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JOURNAL OF
THE FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

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DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXV JANUARY, 1913 NO. 1

SOME RECENT DEVELOPMENTS IN RADIOGRAPHY.[1]

BY

H. CLYDE SNOOK, A.M., M.S.,

Member of the Institute.

DURING the last few years—since 1907—there has been a rapid displacement of the induction coil by a transformer type of apparatus for radiographic work.

The transformer type of apparatus was developed in order to overcome the greatest objections to the induction coil,—namely, the use of " interrupters," very low electrical efficiency, low time factor of secondary current, and limited secondary output from practical sizes of apparatus. The transformer apparatus has successfully overcome these defects of the " coil " and has introduced no real problems of its own.

The first practical transformer type of Röntgen apparatus was installed in the Jefferson Medical Hospital of Philadelphia in June, 1907, where it still is in daily use. Since that time it has been installed in most of the laboratories of the prominent Röntgenologists and hospitals, both of this country and Europe.

It is manufactured in Europe and this country under various

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[1] Presented at the Stated Meeting of the Institute held Wednesday, October 16, 1912.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

names, such as "Interrupterless," "Eresco," "Transverter," "High Potential Rectifier," "Snook Röntgen Apparatus," etc.[2]

This diagram gives the electric circuits and shows the relations of the parts of the Snook apparatus, which in the sizes commonly used in modern hospitals delivers from four to ten kilowatts of electrical energy to the X-ray tube.

The high-tension rectifying switch is maintained in synchronism with the alternating high-tension secondary electromotive force of the high-tension transformer by being attached mechanically to the converter generating the low-voltage alternating current, which is fed to the transformer primary.

FIG. 1.

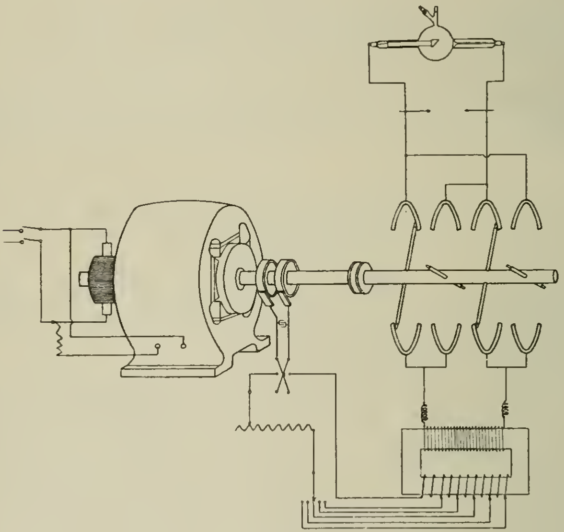

Diagram of Snook Apparatus.

Both the positive and negative half waves are rectified. Also, a substantial part of each half wave is collected so that the time factor of the current will be much higher than in the case of the secondary current of the induction coil. This general arrangement has enabled the manufacturers to use standard transformer construction and to standardize the apparatus on the basis of a wattage output, instead of a spark length rating. It has removed X-ray machines from the class of laboratory apparatus and placed them in the field of electrical engineering.

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[2] See "Die Röntgen Technik," Albers Schönberg, 1908, *Trans. Inst. Röntgen Congress; Archives Röntgen Ray*, 1908.

Rapid radiography of all parts of the human body has been made a matter of only a few seconds for each exposure by this apparatus, and good radiographs with uniform results from day to day are obtained with it.

It is interesting to note that various types of high potential switches have been used and developed. The balanced rotor of the original type of switch is still to-day the one that has proved to be most efficient, mechanically and electrically. A number of these devices have come out since the first one was developed; but the old type of rotor is the one that has preference to-day. It will be noticed that the rotor is a perfectly-balanced piece of apparatus. That is the idea which really made it finally win out, and it is the one that is used to-day. There have been no great improvements in this apparatus since it was placed on the market. It really remains fundamentally and electrically the same as it did when it appeared in 1907.

With it Dr. Groedel and others have developed a pseudo-bioradiographic apparatus. Some have experimented also with enormous induction coils whereby one impulse is passed through the X-ray tube for each exposure. They have succeeded in attaining a speed of about one radiograph every four or five seconds. By making reductions of these radiographs and placing them on a moving-picture film, and by running the moving-picture film through the projection apparatus, at the rate of about eighteen or twenty a second, they have succeeded in making a pseudo-moving picture of radiographic work.

This apparatus has become of some value in the study and examination of the digestive tract by the use of the "Bismuth meal." And that has led to the development of another type of apparatus, which is called the "Vertical Fluoroscopic Apparatus."

This apparatus makes it possible to examine a patient fluoroscopically in the standing position. When the digestive apparatus, with its meal of bismuth subcarbonate, has reached a stage where a radiograph is desired, a radiograph may be made. It is a highly-developed piece of apparatus. Curtains are provided which protect the operator against the secondary radiation which emanates from the patient who is within it, although the patient and operator are able to see each other through a lead glass window.

These extreme precautions are taken for the protection of the operators for the reason that X-rays in their effect upon the human body are cumulative. Like some drugs, strychnine for instance, the effect is a cumulative one, and by the repeated giving of small doses the effect is greatly increased until it becomes a dangerous dosage. The danger to the patient is practically nothing, because the patient receives only a slight dosage during his entire lifetime; but with the operator it is different, since he is working with the radiation daily.

The relation between the X-ray tube, the patient, and the operator with respect to the protective features of the apparatus is such that no X-rays can reach the X-ray operator or be detected outside of the apparatus. This is accomplished by an automatic diaphragm, a large lead box in which the X-ray tube is enclosed, and the curtains, just mentioned, which prevent the secondary radiation from the patient of the interior of the apparatus from getting outside it.

There has been developed a modification of the Snook apparatus for the Medical Department of the United States Army. This apparatus derives its power from an ordinary four-cycle air-cooled gas engine. The entire equipment, including all photographic apparatus and the necessary means of supporting the patient on the standard army stretcher while being radiographed, was made so compact that it can be loaded on one standard army wagon drawn by one pair of mules. This apparatus was exhibited by the Medical Department of the United States Army at the last International Congress of the Red Cross Society, which was held in Washington this year.

There was an exhibit of a portable army type of X-ray apparatus made by the French Government at this same Congress, arranged with and built into a large automobile. This apparatus weighed some 8000 pounds, and was awarded the Grand Prize for X-ray apparatus at the Congress.

A development which is really photographic, but which means a great deal to the X-ray operator who has a large number of plates to handle, is the improvement in stand development which has been made by Dr. David R. Bowen and Dr. G. E.

Pfahler, of Philadelphia. Economy of space is an important thing even in the Röntgen laboratory, and the efficient utilization of the cubical contents of the laboratory is a big problem with the growth of cities, the increase in density of population, and the high fixed charges on each foot of floor area.

If the X-ray operator should in one day have to develop thirty or forty plates from the 8-inch-by-10-inch size up to 14-inch-by-17-inch, and were to lay them out on horizontal trays, he would utilize a large floor area with its corresponding cubical contents. Tank development which utilizes the cubical contents of the dark room very efficiently enables the operator to develop, fix, and wash a great many more plates with a fewer number of motions than if the plates are developed in horizontal trays.

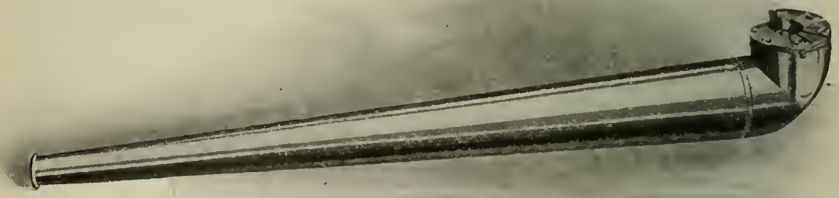
Dr. Bowen has developed a plate-holder frame which in combination with proper vertical tanks enables the operator to realize this economy in space in a most practical manner.

Several water motor types of tray rockers have somewhat displaced the noisy electric ones which up to about a year ago were most popular for the automatic rocking of photographic trays during plate development. These water motor tray rockers, while better than the electric rockers, are useful in helping to solve the problem identified with what might be termed " the retail " development of plates. The stand development, the separate frames for holding each plate—*a la* Dr. Bowen—is the best thing which yet has appeared for what might be termed the " wholesale " development of photographic or X-ray plates.

In photographic plates there has been a real development during the last year. Photographs and amateurs know full well that the rapid plate has a coarse-grained emulsion; that is to say, the general rule is that rapid plates have coarse-grained emulsions. During the last year I have tested at least three makes with fine-grained emulsions that are really quite rapid. These plates are all of English make, and American makers are doing their level best to imitate the results. One interesting thing about these rapid plates is that they have an unusually high percentage of silver. This percentage of silver is about 35 per cent. greater than any of the rest of the X-ray plates. The increased absorption of X-rays by this large percentage of silver in the emulsion is one of the things, of course, that cause the increased transformation of the X-ray energy into chemical energy and increase the speed of the plate. But there are two types of plates only that have proved very successful with fine-grained emulsions and with a much smaller percentage of silver. I do hope that our manufacturers will find out what to do to give the beautiful surface and the rapid speed of some of these English plates.

The Pfahler-Benoist penetrometer, which is used for determining the degree of penetration of the X-rays emanating from the X-ray tube, is another comparatively recent important development. This apparatus consists of a long tapering tube at the large end of which is mounted the penetrometer proper. The penetrometer itself has in its centre a disk of silver 11/100 millimetre thick, and around it is placed a stairway of aluminum sectors, each step of which is one millimetre thick. Immediately behind this assemblage of sectors and silver disk is a barium platino cyanide screen. Beyond it, at an angle of 45 degrees, is a mirror arranged so that the operator by looking into the large tube can see the fluoroscopic image produced by the aluminum sectors and silver disk.

FIG. 2.



Pfahler-Benoist Penetrometer.

Dr. Benoist discovered the fundamental fact that 11/100 millimetre of silver offers a fairly constant absorption to Röntgen radiation of all degrees of hardness. The varying steps of aluminum thickness have variable absorption for variable degrees of X-ray penetration. The operator, therefore, simply by matching the shadow of the silver disk against the shadows of the aluminum sectors, is able to read the hardness factor of the radiation. This is the most accurate method in existence to-day by which to measure the degree of penetration of the radiation emanating from an X-ray tube.

Another important recent development is the improved Sweet eye localizer, which is the work of Dr. Wm. M. Sweet, a celebrated eye surgeon, who for a number of years has used the eye localizer which he has tried to get other people to use, but has been somewhat unsuccessful because of the difficult technique. This new apparatus was developed by Dr. Sweet so that the difficulties of technique could be reduced to mechanical operations.

A focal co-ordinate reference plate and a reference chart are used in conjunction with the radiographs to provide the proper mechanical recording of measurements which are necessary to locate the foreign body in three-dimensional space.

This apparatus was fully described by Dr. Sweet in recent articles in the *Archives of the Röntgen Ray* and elsewhere, so that a full description is omitted here.

Another development which within the last two years has made great headway in both Europe and in this country has been stereoscopic radiography. This has been due to a comparatively recent recognition of the correct optical principles which underlie proper technique in this work. Some form of Wheatstone stereoscope is usually employed.

The obvious advantages of this method of procedure in radiography do not require elaboration. The advantage of having the parts radiographed in three dimensions,—that is, stereoscopically,—is very great in the cases of fractures, foreign bodies, skull and lung examinations.

Recent developments in the quality of intensifying screens have enabled the X-ray operator to increase the speed with which he makes radiographs, so that about one-fourth the former time of exposure is required. The modern intensifying screen consists, usually, of a piece of cardboard, one side of which has a coating of calcium tungstate.

Mr. Edison and others, shortly after Röntgen made his discovery, experimented with various kinds of intensifying screens.

The crystals of these early intensifying screens were too large to be of practical use, because of the mottling which they produced on the photographic plates. The surface of the early screens was very rough indeed, while the surface and the size of the particles in the sensitive side of the modern intensifying screen are usually smaller than the grain of the photographic emulsion. The modern screen, therefore, does not cause an appreciable mottling of the photographic plate.

The radiographs are usually taken with the radiation passing through the photographic plate before the radiation strikes the screen, because of the fact that X-ray absorption of the tungsten salt is greater and less uniform than the absorption of the glass plate and the photographic emulsion. These screens all give a bluish-white light, so that they are quite efficient in producing actinic effects upon the photographic emulsion.

The developments in X-ray tubes recently appearing include the so-called Bauer air regulator, which is a device for admitting ordinary atmospheric air into X-ray tubes from time to time when the vacuum of the tube needs reducing.

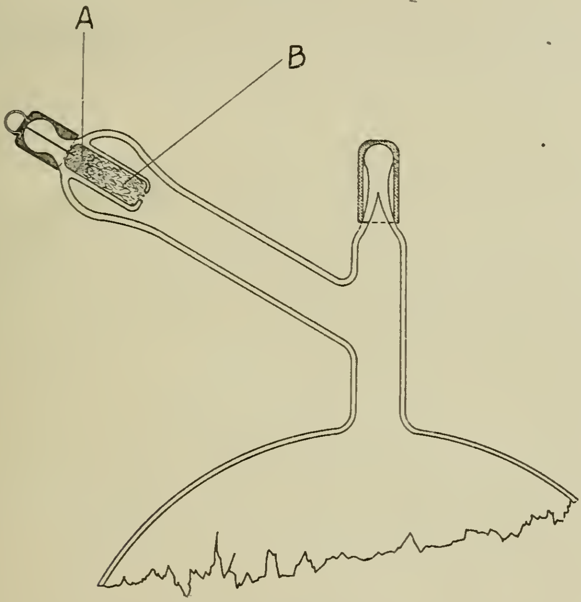
The regulator has attached to it a large rubber tube and a rubber bulb or other device that may be squeezed in order to compress the column of air in the rubber tube, which in turn pushes a small column of mercury in a capillary tube, and this by its movement exposes a plug of porous material through which a small amount of atmospheric air may diffuse into the X-ray tube.

This regulator has proved to be quite satisfactory and is used to a large extent in Europe, because of the fact that atmospheric air gives a better characteristic to the vacuum of the X-ray tube than the gases admitted by the ordinary chemical regulators previously in vogue. This is a deserving and meritorious improvement which has added to the ease and convenience of reducing the vacuum of the X-ray tube.

Now I have the privilege of calling your attention to what I think is the first really commercial application of radium. This, I believe, is the first announcement, and it gives me very great pleasure to have the privilege of making it to The Franklin Institute. Briefly, it is the use of a powdered uranium-radium ore in the X-ray tube regulator as a gas-producing material to liberate gaseous helium at the will of the X-ray operator.

Referring to Fig. 3, *A* is a mass of powdered clevite, Bröggerite, or other ore which, due to atomic disintegration, is constantly producing within its own volume gaseous helium or other monatomic gas. This mass of powdered mineral is mixed with a small percentage of asbestos wool in order to introduce appreciable resistance between the highly-conducting particles of crushed ore. *B* is a packing of asbestos wool for the purpose of holding *A* mechanically at the upper end of the glass tube within which it is contained and to keep it in contact with the conductor which leads to it through the glass seal.

FIG. 3.



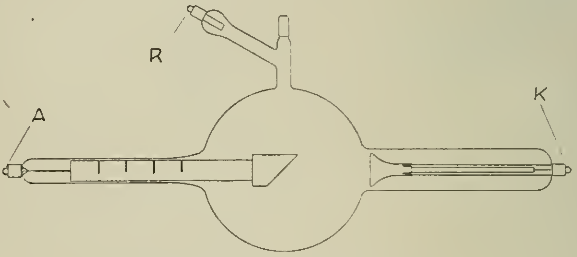
Helium Regulator for X-ray tubes.

A, powdered solid containing helium gas; *B*, plug of asbestos.

Uranium is the atomic parent of radium. Radium likewise breaks down and evolves helium, due to atomic disintegration. Clevite and Bröggerite are two of the minerals which occlude the helium gas as rapidly as it is formed within its own volume. These minerals will yield this gaseous helium upon heating or upon being dissolved in strong acids. In the X-ray tube regulator the powdered mineral conveniently retains the self-generated helium gas until it is required and liberated by passing a high-tension discharge through it, which liberates the gas by heating.

The advantage which gaseous helium has in an X-ray tube is the fact that its resistance to the passage of the electric current is small as compared with the common gases or any other gases that are readily available. The dielectric cohesions, or resistances to the passage of the electric current, of the rare gases of the atmosphere are as follows: Neon, 8.5; helium, 18.5; argon, 120, while that of air itself is 460. It is seen that neon would be more suitable as a gas to make the electrical resistance of the X-ray tube low than helium itself. Neon, however, is not readily obtainable, is exceedingly rare, and is not conveniently capable of being used in the X-ray tube in even the small commercial quantity needed for X-ray tubes.

FIG. 4.



X-ray tube with Helium Regulator.

A, Anode; *K*, Kathode; *R*, Regulator.

Helium is the best available gas, since Nature has kindly provided the uranium minerals which generate and hold the helium gas until it can be liberated in a tube regulator, in the manner above described.

I make this statement because I believe that the dielectric cohesion of neon is the lowest of all the known gases, and because helium is next to neon in its low electrical resistance.

The so-called "crankiness" of X-ray tubes which X-ray operators find in the case of old X-ray tubes is due to the presence in the X-ray tube of gases of very high dielectric cohesion. These gases are set free by electric discharge through X-ray tube regulators provided with mica, or asbestos, near the end of the life of these gas-producing materials when used as such in X-ray tube regulators. Glass itself gives off gas having very high dielectric cohesion when the glass is heated in a vacuum. Since this condition exists in an X-ray tube when strongly operated, the inner surfaces of the walls of the X-ray tube liberate gases having high electrical resistance and thereby producing the so-called "cranky" tube.

Tubes with these helium-radium-uranium regulators do not exhibit the crankiness above described and give a larger percentage of X-ray energy output for a given input of electrical energy than X-ray tubes otherwise identical except of the kind of gases used to regulate them. This increase in X-ray energy output for a given electrical energy input is approximately 20 per cent. as compared with similar X-ray tubes using atmospheric air for their regulation.

It is an exceedingly fascinating idea to realize that the helium gas within an X-ray tube using one of these radium regulators is obliged within the X-ray tube for a second time to perform the function of being the matter or stuff connected with the production of corpuscles and positively-charged carriers of electricity. In the atomic disintegration of the radium this helium was the very identical matter constituting the alpha particles given off by the radium. Now in the X-ray tube it is again required to furnish the material from which are made the positive particles which correspond to the alpha rays of radium and the kathode rays which correspond to the beta rays of radium.

Discussion.

DR. GOLDSCHMIDT.—I would like to ask how recent that fluorescent screen is.

MR. SNOOK.—This calcium tungstate intensifying screen has been in practical use really since 1910, but the practical development of the screen so that it would withstand rough usage has occurred only within the last year. The matrix,—that is to say, the binder, with which the crystals of the salt were held together,—was originally a soluble gum. The result was that finger-prints would show very quickly. The later screens, which have been made practical this year, have had a matrix of celluloid or nitrated cellulose, so that they are quite durable, and do not show finger-prints. They actually can be wiped with a damp cloth.

A MEMBER.—I am surprised about the statement that the small crystals are visible. Years ago I examined such a plate with a contact lens, and I could not see any crystals; I could see a fine powder.

MR. SNOOK.—That is really true. It is practically large crystals powdered; but in the powder one finds many very fine crystals.

A MEMBER.—Well, sulphide of zinc is used for the same purpose, is it not?

MR. SNOOK.—No, it is too strongly phosphorescent, and does not exhibit so high an efficiency; it is not an efficient transformer of X-rays into light.

Q.—It is rather weak, is it not?

A.—Yes.

MR. HORNOR.—Do you use tungsten electrodes?

MR. SNOOK.—There are so many things that might have been brought to your attention, and I beg your pardon for having failed to call your attention to that phase of the subject.

The focus spot of the X-ray tube must be made of a material that will withstand very high temperatures. It must also be strong mechanically and have good thermal conductivity. Such a material, with better thermal conductivity and with a higher melting point and better mechanical properties than the material we have used until a year ago, is to be found in the ductile tungsten which has been placed on the market by the General Electric Company. The material which was used prior to the use of tungsten was usually platinum or a platinum-iridium alloy. Perhaps 20 per cent. was the highest successful percentage of iridium alloyed with platinum. Iridium has a higher melting point than platinum, and alloyed with platinum raises the melting point and thus makes a target with good resistance.

Prior to the introduction of tungsten the target had a melting point of about 1750° centigrade, whereas the melting point of tungsten is approximately 3000° C. When you realize its thermal conductivity,—that is, when you consider the ability of the metal to conduct the heat away from the focus spot (the tungsten has about twice that of platinum when the tungsten is first placed in the tube),—it has an enormous advantage over platinum or its alloys that has been an exceedingly great help.

MR. G. R. HORNOR.—Did I understand you to say that helium made a tube more efficient than argon?

MR. SNOOK.—Considerably. And argon is more efficient than atmospheric air, and atmospheric air is more efficient than the oxygen which is obtained from such materials as potassium chlorate, manganese dioxide, and other chemicals which on heating will give off gaseous oxygen. Argon is more efficient than nitrogen, but helium is the most efficient gas I have been privileged to use.

MR. HORNER.—Did you say that radium itself disintegrates into helium gas?

MR. SNOOK.—Yes, it does. One of the earliest experiments was to place some radium in an X-ray tube, and the idea was to utilize the helium given off by radium. Radium, however, does not hold gaseous helium, but gives it off freely, and therefore the free gas in the tube constantly became of greater and greater pressure and the vacuum went down in a most disappointing manner; whereas with the minerals we use the helium does not become a free gas until the mineral is heated by the electric discharge, when desired.

MR. HORNOR.—How do you introduce the free gas into the tube?

MR. SNOOK.—I will demonstrate by the tube on the machine. (*Practical demonstration.*) It will be seen that the main terminals of the generating apparatus are directly connected to the main terminals of the X-ray tube. It will be seen also that the regulator terminal is insulated by not being connected to anything. If now I rotate this arm, so as to get the high tension over from the anode to the regulating terminal, I can pass the discharge through the X-ray tube regulator. I will demonstrate this. (*Demonstration.*)

Now, changing the connection back, we measure the parallel spark gap in that distance, and it is less than 2½ inches. Changing it back and lowering it again, we have a little over 1½ inches.

Soldering Aluminum by a New Aluminum Alloy. ANON. (*Sci. Amer.*, cvi, 22, 491.)—An English method of soldering aluminum, especially applicable to electrical conductors of this metal, is claimed to produce a permanent contact and to withstand the most searching atmospheric and chemical tests. Recognizing that many attempts hitherto made have failed on account of the aluminum oxide that creeps under the coating of solder, and destroys the contact, the new method employs a solder composed of an alloy of aluminum and the necessary flux, and is applied as a paste. The heat of an alcohol lamp or gasolene blow-torch, or the acetylene-oxygen welding flame (for large work), causes the solder to run freely into the joint; and in connecting heavy-stranded aluminum cables a special method is employed whereby molten aluminum is poured into the joint.

Researches on Glass and Porcelain Insulators. G. REBORD. (*Atti dell' Assoc. Elettr. Ital.*, xiv, 665.)—Experiments were made on the electrical and physical properties of glass and porcelain insulators of European and American manufacture. To clear up some discrepancies on the disruptive voltages obtained with needle points by H. W. Fisher, new experiments were made with points really pointed and not blunt, such as were frequently found in commercial needles. A table, and the curve plotted therefrom, are given, showing the results obtained, which are expressible in these formulæ: from 0 to 25 kilovolts $X = 1.3\ V$, where V is effective pressure in kilovolts and X the sparking distance in mm.; from 50 to 150 kilovolts $X = 3.2\ (V—25)$; a third, less accurate formula for voltages between 30 and 50 kilovolts is $X = 2\ (V—10)$. The summary of the insulator tests may thus be given. Glass insulators have a superficial resistance not inferior to that of porcelain under various conditions of humidity, and the glass does not retain moisture to any greater extent. The sparking distances over glass and glazed porcelain are from 10 to 30 per cent. lower than the sparking distances in air; ebonite, ambroin, and unglazed porcelain show similar behavior. When smooth, the curved surfaces of glass and porcelain are equivalent. The mechanical strength of glass is satisfactory and the surface is unattackable, but glass will not stand sudden jumps in temperature as well as porcelain does.

Melting Point of Copper Oxide. R. E. SLADE and F. D. FARROW. (*Z. Electrochem.*, xviii, 817.)—Pure cupric oxide does not melt below 1148° C. At this temperature, even with a pressure of 2.5 atmospheres of oxygen, decomposition occurs, producing cuprous oxide, which forms a solution with the cupric oxide solidifying at about 1081° C. At 1 atmosphere the decomposition begins at 1090° C., and the solution, containing over 50 per cent. of cuprous oxide, solidifies at about 1064° C. This is the value given for the true melting point of copper oxide by Wöhler.

SAFETY OF LIFE AT SEA.[1]

BY

JAMES DONALD, Consulting Naval Architect,
Member of the Institute.

The subject of the safety of life at sea is at the present time a very interesting and important one. It will be found, after investigation, that a greater amount of attention has been given by the various nations to this subject than is generally known by the public.

A historical review of the means of saving life at sea before the days of iron and steel ships would not be of interest to us, seeing that the conditions are so different as regards the capability of the wood vessel to float longer than the iron and steel one in case of accident, owing to the material used, and to the fact that wooden ships had more freeboard. The history of the safety of life at sea, therefore, only concerns us from about the year 1850.

In order to place before you in a concise way the laws, etc., relating to the safety of life at sea, your attention will be directed to those of Great Britain, as described in Blue Books lately issued, and this information will be useful in our consideration of the navigation laws of the United States.

We find in the history of transportation on land that regulations had to be made as regards safety of life on railways, street cars, etc., as the different means were developed. The same applies to transportation on the ocean. The great pity is that these laws are always amended to suit the developments of the business after some terrible sacrifice of life due to want of forethought.

In order to ensure safety of life at sea consideration must be given to the vessel generally and in detail, and to all that affects her navigation; the following list will give you an idea of the subjects relating to safety:

Stability, with special reference to vessel in light condition and worst possible loaded condition; stability of passenger vessels with majority of passengers on upper passenger deck; stability of vessels in rough weather.

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[1] Presented at the meeting of the Mechanical and Engineering Section held Thursday, October 24, 1912.

Freeboard, or amount of reserve buoyancy, with special reference to cargo vessels in rough weather.

Design, as regards subdivision into watertight compartments; design, as regards sanitation; design, as regards ventilation; design, as regards area of living spaces.

Construction, as regards quality and strength of materials; construction, as regards scantlings of structure.

Equipment, as regards instruments for navigation; equipment, as regards lights for navigation; equipment, as regards means of fire prevention in passenger and freight spaces; equipment, as regards life-boats, etc., and launching of same.

Manning, as regards crew and duties of crew.

Inspection of materials at mills; inspection of construction in ships; inspection of vessel's equipment in ship; inspection of crew as regards capability; inspection of vessel annually; inspection of vessel when sailing from and arriving in port.

As it would be impossible to take up all these subjects in detail in one paper, it is proposed to place before you a general outline of what has been done by Great Britain and the United States as regards ensuring safety of life at sea, more particularly by means of life-saving appliances and by the watertight subdivision of vessels.

As regards safety of life at sea, your attention is now directed to what has been done in the Merchant Marine of Great Britain:

In July, 1912, the British Government appointed a committee, called the Merchant Shipping Advisory Committee, and it was asked to report on the statutory regulations as to boats and life-saving appliances and the means of ensuring safety of life at sea. This committee consisted of representative shipowners, shipbuilders, marine engineers; and members of the Board of Trade, of classification societies, and of chambers of shipping. This committee was assisted by representatives of the British Admiralty, Post Office, Meteorological Office, Hydrographic Office, and by wireless experts. Sub-committees were formed to report on type of open life-boats, wireless telegraphy, steamship routes, home-trade passenger ships and statistics.

The sub-committee on statistics reported that " in 1855 there were three sets of regulations in force, dealing with:

"*First.*—Vessels carrying emigrants.

"*Second.*—Other vessels carrying passengers.

"*Third.*—Seagoing vessels not carrying passengers.

"The first regulation contained a boat scale regulated by the tonnage of the vessel, but no greater number of boats was necessary than sufficient to carry all the persons (crew as well as passengers) on board the vessel.

"The second regulation contained a boat scale regulated by the tonnage of the vessel, and was drawn up for vessels up to 1,000 tons; no requirement was made that the boats should be sufficient to carry all persons on board the vessel, but the Board of Trade always required additional life buoys and buoyant deck seats, etc., to be carried on home-trade passenger ships carrying large numbers.

"The third regulation contained a boat scale identical to that required by the second regulation, but this was not enforced, as the Board of Trade had no power to enforce its observance."

In 1886 a committee appointed by the Board of Trade reported that a great number of vessels employed on the Atlantic service had not enough life-boat accommodation, though many shipowners fitted more life-boats than called for by the rules, and this committee recommended "that each ship shall have sufficient life-saving gear for all on board at any one time."

In 1887 a select committee of the House of Commons was appointed to report on saving of life at sea, and they reported "that many passenger ships could not, without great inconvenience, carry so many of the ordinary wooden boats as would suffice to carry the whole of the passengers and crew with safety in bad weather. Under such circumstances the crew would not be sufficient to man so many boats; nor could they all be gotten into the water in sufficient time, in the event of very rapid foundering. Having regard, however, to the fact that accidents occur probably as often in moderate weather as in bad, and having regard also to the fact that the very cause of the accident frequently incapacitates many of the boats, and to the further fact that an insufficiency of boats undoubtedly tends to cause panic, we are of opinion that all sea-going passenger ships should be compelled by law to carry such boats, and other life-saving apparatus, as would in the aggregate best provide for the safety of all on board in moderate weather."

As a result of the report of the select committee in 1887 new rules came into force in 1890. The boat scale then adopted was that in force in June, 1912, except that the maximum tonnage provided for was 9,000 tons. The table was, however, extended in 1894 to provide for vessels of 10,000 tons. But as regards emigrant ships, there was a rule that if there was not life-boat accommodation for all on board, additional boats or rafts were to be carried, and these additional boats or rafts should have carrying capacity so that they and the boats required by the table should provide three-fourths more than the minimum capacity required by the table. This rate was no doubt worked out so as to have life-boat capacity generally for all on board, but ships increased in size and the rule did not apply.

In the report of the select committee of the House of Commons in 1887 the following reference was made to watertight bulkheads:

"Though the question of construction was clearly not included in the reference to the committee, still they think it only right to state that, having heard the evidence, the proper placing of bulkheads, so as to enable a ship to keep afloat for some length of time after an accident has occurred, is most important for saving life at sea, and a thing for which the full efficiency of life-saving appliances largely depends." This recommendation is responsible for the rule in the merchant shipping (life-saving appliances), October, 1888, as follows:

"WATERTIGHT COMPARTMENTS.—When ships of any class are divided into efficient watertight compartments to the satisfaction of the Board of Trade, they shall only be required to carry additional boats, rafts, and buoyant apparatus of one-half of the capacity required by these rules; but the exception shall not extend to life jackets or similar approved articles of equal buoyancy suitable to be worn on the person."

Shipowners were not required to build to this rule; they could carry life-boats according to the boat scale based on the tonnage of the vessel, or they could take advantage of the rule specifying watertight bulkheads and requiring boat capacity for one-half the capacity required by the boat scale rule. Speaking generally, recourse to this watertight compartment rule by shipowners has been so insignificant that the rule may be regarded as of no practical account.

In 1890 a committee, called the Bulkhead Committee, was appointed by the British Government, and consisted of practical men experienced in the latest practice of ship design, shipbuilding, and marine engineering. The report made by the Bulkhead Committee is a valuable addition to the subject of safety of life at sea. Their report contains recommendations regarding how vessels should be grouped for watertight subdivision, with tables giving the spacing of bulkheads. The report also contained recommendations regarding bulkhead decks, longitudinal bulkheads, sidelights, freeboard, openings, and construction of bulkheads.

The watertight subdivision of steamers to ensure more safety of life at sea was not used in the design of ships until after the Bulkhead Committee report was issued. This committee simply made recommendations which were never included in any law. A number of owners of passenger vessels followed these recommendations in vessels operated in the British Channel services and in vessels on the Atlantic Ocean trade with the idea of attracting business.

After 1894 passenger steamers were built of larger tonnage than 10,000 tons, and increased to 40,000 tons at the present time. The reasons given for not increasing the life-boat capacity to meet the larger number of passengers carried are:

There was a small loss of life under the prevailing regulations.

Vessels were stronger and had watertight subdivisions.

Not considered possible that a larger number of life-boats could be rapidly dealt with at sea and could be safely housed without encumbering the decks unduly.

Vessels were safer owing to definite routes being agreed upon.

Vessels were fitted with wireless telegraphy, ensuring assistance.

If more boats were carried it would not be possible to man them in case of accident.

Vessels were fitted with twin, triple and quadruple screws, ensuring more chances of proceeding in case of accident to machinery.

In 1910 and 1911 a number of recommendations were made to increase the life-boat capacity of passenger steamers, but none of these were enacted into law.

The above-mentioned rules appeared to be sufficient to ensure safety of life at sea, according to statistics made by the Board of Trade, until we come to the *Titanic* disaster.

It will be interesting to quote some particulars regarding sea casualties from the Board of Trade returns. The following is a summary of the vessels registered in the United Kingdom which were totally lost at sea or met sea casualties attended with loss of life during the twenty years ended June 30, 1911, while on voyages between European ports and ports on the east coast of the United States, Canada, and Newfoundland:

	Number of casualties.	Number of lives lost. Crew.	Pass.	Total.
Sailing vessels	100	221	7	228
Steam vessels	332	1,349	78	1,427
	432	1,570	85	1,655

The casualties are divided into:

Founderings	51
Strandings	115
Collisions	17
Other causes	201
Missing vessels	48
	432

Under "Other causes" there do not appear to have been more than about 29 in which boats could have been of assistance in saving life. Referring to the 85 passengers lost, 44 of these were lost in one vessel which stranded on the Manacles in Cornwall, England.

Another return relating to the home-trade or excursion passenger steamers registered in the United Kingdom which met with casualties attended with loss of life during the twenty years ended June 30, 1911:

	Number of vessels	Number of lives lost		
		Crew	Passengers	Total
Founderings	1	21	14	35
Strandings	8	104	273	377
Collisions	13	8	44	52
Other causes	13	18	10	28
Totals	35	151	341	492

In 30 out of the 35 cases boats and buoyant deck seats were sufficient to accommodate all persons on board.

Another return showing the number of sea casualties involving loss of life to vessels registered in the United Kingdom reported to the Board of Trade during the twenty years ended June 30, 1911, as having occurred *everywhere* through contact with ice:

Out of 858 casualities through contact with ice, only 3 entailed loss of life, and the total number of lives lost being 6.

Of the vessels totally lost, 13 were lost through striking ice on voyages between European ports and the east coast of the United States, Canada, and Newfoundland, and in these 13 casualties there was no loss of life.

The recorded number of passengers carried almost entirely in British vessels between the United Kingdom and ports in the United States and British North America during the years 1892–1911 was 9,390,094. The total number of passengers who lost their lives from all casualties to British vessels in the North Atlantic was 85.

Then in April, 1912, occurred the greatest marine disaster that ever happened, in the loss of the passenger steamer *Titanic* and 1,490 lives after colliding with an iceberg in the North Atlantic Ocean. Details of the vessel and description of the voyage and of the disaster will be found in the Reports of the Enquiries made by the United States and British authorities.

The British Government appointed the Merchant Shipping Advisory Committee in July, 1912, already mentioned. This committee recommended in the case of steamships carrying emigrant passengers and foreign-going passenger steamships not carrying emigrants that:

First.—The stability and seaworthy qualities of the vessel itself be regarded as of primary importance, and every provision made against possible disaster be subordinated to this primary consideration.

Second.—The existing scale based on gross tonnage of vessel as revised be used in regard to number of boats carried under davits.

Third.—The existing scale regarding number of boats to be increased by the addition of collapsible boats and life rafts sufficient for all on board.

In the case of steamers carrying passengers in cross-Channel services, they should have sufficient accommodation to support 50 per cent. of the passengers and crew allowed within the limits of the home trade in life-boats, life-rafts or buoyant apparatus. It is also recommended in the case of these steamers in the winter, when they may have more passengers and crew than could all be carried in the buoyant apparatus, that these steamers should be fitted with wireless telegraphy.

In the case of steamers carrying passengers in estuaries or mouths of rivers the boats and buoyant apparatus should be sufficient to keep afloat at least 50 per cent. of total number of passengers and crew.

In the case of passenger steamers plying in inland waters buoyant apparatus should be fitted for 25 per cent. of the number of passengers and crew.

All other vessels to have life-boats sufficient to carry all on board.

Recommendations were also made relating to manning of ships' boats and drill, wireless telegraphy, routes, speed. inspection. etc.

UNITED STATES.

In the report of the Supervising General of the Steamboat Inspection Service dated 1905 we find a short history of the laws respecting safety of life at sea.

The act of Congress approved July 7, 1838, which provided for the inspection of the hulls and boilers of steam vessels, was the first legislation upon the important question of "better security of lives of passengers on board vessels propelled in whole or in part by steam." By this act the inspectors were appointed. This act provided for life-boats, signal lights, fire-pumps and hose, and also for rods or chains for steering gear. There were also rules made for inspection of boilers and hulls. Modifications were made to this act on March 3, 1843, regarding the steering apparatus. The act of Congress approved August 30, 1852, was really the establishment of the Steamboat Inspection Service. This act provided for life-saving appliances, licensing of crew, and inspection of machinery. Modifications were made in 1853, 1864, 1865, and 1866. The act of Congress approved February 28, 1871, provided for the organization and administration of the Steamboat Inspection Service, and is the basis of our present practice. The effect of its operation has been to lessen the loss of life. The Supervising General, in this historical review in 1905, says that there yet remains much to be done toward the further protection of human life on shipboard, and recommendations were added to his review. Those referred to carrying petroleum in passenger steamers, vessel's certificates, marine boilers, crew, pumps, inspection, and fire-proof steamers. These recommendations referred chiefly to engineering rules which are very essential and the enforcement of which has saved a large number of lives, but no mention is made of life-boats, watertight subdivision, or freeboard.

We now proceed to a short description of the organization and administration of the Steamboat Inspection Service and to the laws and rules relating chiefly to construction, watertight subdivision, and life-saving by buoyant apparatus.

The law authorizing the supervision of the inspection of vessels is as follows:

1871 (R. S. 4402) "There shall be a supervising inspector-general, who shall be appointed . . . by the President, ... who shall be selected with reference to his fitness and ability to systematize and carry into effect all the provisions of law relating to the Steamboat Inspection Service, ..."

1871 (R. S. 4403) "The supervising inspector-general shall, under the direction of the Secretary of Commerce and Labor, superintend the administration of the steamboat-inspection laws. . . . . report . . . . to the Secretary of Commerce and Labor . . ."

1871 (R. S. 4404) "There shall be ten supervising inspectors, ... Each of them shall be selected for his knowledge, skill, and practical experience in the uses of steam for navigation, and shall be a competent judge of the character and qualities of steam vessels, and of all parts of the machinery employed in steaming." Each supervising inspector has a number of assistants, who are called local inspectors of hull and local inspectors of boilers.

1871 (R. S. 4415) " The inspector of hulls shall be a person of good character and suitable qualifications and attainments to perform the services required of an inspector of hulls, who from his practical knowledge of shipbuilding and navigation and the uses of steam in navigation is fully competent to make a reliable estimate of the strength, seaworthiness, and other qualities of the hulls of vessels and their equipment deemed essential to safety of life in their navigation; and the inspector of boilers shall be a person of good character and suitable qualifications and attainments to perform the services required of an inspector of boilers, who from his knowledge and experience of the duties of an engineer employed in navigating vessels by steam, and also of the construction and use of boilers, and machinery and appurtenances therewith connected, is able to form a reliable opinion of the strength, form, workmanship, and suitableness of boilers and machinery to be employed, without *hazard* to life from imperfection in the material, workmanship, or arrangement of any part of such apparatus for steaming."

The territory embraced in the supervising districts is as follows:

" First District embraces all waters and rivers of the United States west of the Rocky Mountains, and the Hawaiian Islands.

" Second District embraces all the waters of Long Island Sound west of the Connecticut River and the tributaries thereto, that portion of Long Island lying west of Riverhead and the waters of the Atlantic Coast, rivers, and tributaries from Long Island to Cape Charles.

" Third District embraces the waters of the Atlantic Coast, rivers, and tributaries between Cape Charles and Cape Sable.

" Fourth District embraces the Mississippi River and tributaries from above Greenfield, Mo., to the head of navigation on the Missouri River, and to the head of navigation on the Illinois River.

" Fifth District embraces the waters of the Atlantic Coast, rivers, and tributaries from the eastern boundary of the United States to and including the Connecticut River, and that portion of Long Island east of and including Riverhead.

" Sixth District embraces the Ohio River and tributaries up to and including Carrollton, Ky., and the Mississippi River and tributaries from Greenville, Miss., up to and including Greenfield, Mo.

"Seventh District embraces the Ohio River and tributaries above Carrollton, Ky.

"Eighth District embraces all the waters of the Great Lakes north and west of Lake Erie, with their tributaries.

"Ninth District embraces all the waters of the River St. Lawrence, Lakes Erie, Ontario, and Champlain, and their tributaries.

"Tenth District embraces the coast and tributary waters of the Gulf of Mexico, between Cape Sable and the mouth of the Rio Grande, and the Mississippi River and tributaries to Greenville, Miss., and Porto Rico."

1871 (R. S. 4405) "The supervising inspectors and the supervising inspector-general shall assemble as a board once in each year at the city of Washington, D. C. . . . . in January, ... for joint consultation, ... The board shall establish all necessary regulations required to carry out in a most effective manner the provisions of the laws relating to the Steamboat-Inspection . . . . and such regulations, when approved by the Secretary of Commerce and Labor, shall have the force of law." . . . .

The navigation laws of the United States consist of statutes passed by acts of Congress, and which statutes cannot be amended unless brought up before Congress in an act and voted upon.

From the above-quoted statutes referring to the duties of the supervising inspectors it will be seen that they must rigidly follow the statutes, and the supervising inspectors have the power to draw up new regulations (which are actually as compulsory and important as the statutes) in conference with the shipping and ship-building interest affected by the same. These new regulations are then submitted to the Secretary of Commerce and Labor, and, according to R. S. 4405, when they are approved by him they have the force of law.

To quote again from the navigation laws:

"Part VI, Paragraph 113. Unseaworthy Vessels.

"If any person knowingly sends or attempts to send or is party to the sending or attempting to send an American ship to sea, in the foreign or coastwise trade, in such an unseaworthy state that the life of any person is likely to be thereby endangered, he shall, in respect of each offence, be guilty of a misdemeanor, and shall be punished by a fine not to exceed one thousand dollars, or by imprisonment not to exceed five years, or both, at the discretion of the court, unless he proves that either he used all reasonable means to ensure her being sent to sea in a seaworthy state, or that her going to sea in an unseaworthy state was, under the circumstances, reasonable and justifiable; and for the purposes of giving that proof he may give evidence in the same manner as any other witness. (This section shall not apply to fishing or whaling vessels or yachts—December 21, 1898, sec. 26.)"

"*Part VI, Paragraph 114. Inspection of Hulls and Equipment.*

"The local inspectors shall, ... carefully inspect the hull of each steam vessel . . . . and shall satisfy themselves that every such vessel . . . . is of a structure suitable for the service in which she is to be employed . . . . and is in a condition to warrant the belief that she may be used in navigation as a steamer, with safety to life, and that all the requirements of law . . . . are faithfully complied with; . . . ."

By referring to R. S. 4415 we read that the inspector of hulls must be a person who is fully competent to make a reliable estimate of the strength, seaworthiness, and other qualities of the hulls of vessels and their equipment deemed essential to safety of life in their navigation.

Taking the strength of vessels first, there are no regulations specifying what the materials or scantlings or inspection of the same should be, though if we look at the rules for the construction of life-boats we find every part specified in detail. Of course, it may be argued that it is not necessary to have a set of rules of scantlings, etc., as vessels are generally classed in some classification society for insurance purposes; but no mention is ever made in the regulations that vessels should be built of materials and scantlings equal to any classification society's rules. It evidently was expected, according to the reading of the statute, that the local inspector was to estimate the strength and pass on the same, but he has not the time besides his other duties, and it would mean that every inspector would have to make a set of tables, etc., for his own district. Again, the same Statute 4415 says that the local inspector is to be competent and make reliable estimate of the scantlings and other qualities of the hulls necessary for safety of life. This again brings in the question of strength and also freeboard, a subject that is not mentioned in the navigation laws. The majority of vessels at present have high freeboard on account of the type of vessel used in the coasting trade, but a large number of freight steamers are in existence and being built which can be loaded to any draft, irrespective of safety. All other nations have rules regulating the freeboard. Among "the other qualities of the hulls" mentioned in the statutes there is a very important one in the subdivision of vessels by watertight bulkheads. This requirement was forcibly brought out in the *Titanic* disaster, and, in my opinion, is the most important means of ensuring the greatest safety of vessels at sea, whether in fogs, collisions, or grounding. There is no mention made in the navigation laws of double bottoms, a prevention that has been in practice for 25 years in vessels of other nations.

This subject of watertight subdivision has been thoroughly investigated, and vessels of the U. S. Navy have been and are now subdivided into watertight compartments so as to ensure the greatest safety in case of accident. As already mentioned, the British Government, in 1890, appointed a Bulkhead Committee to report and draw up rules for subdivision of vessels by watertight bulkheads. By reference to this report it will be seen that it was assumed that vessels carrying passengers should be able to float when any two adjacent compartments were damaged and liable to be flooded. The report contained rules for the construction of watertight bulkheads to withstand the pressure of water that would result from such flooding of spaces. This basis of two adjacent flooded compartments was assumed, as it appeared to suit the worst condition that would happen, and was not placing such rigid requirements that would hinder a vessel from being a paying proposition in the carriage of passengers and freight. And the subdivision was not enforced by law, as new vessels would be at a disadvantage compared with vessels built before the report was made. Passenger steamship companies followed the recommendation so as to ensure safety to their passengers and attract business. The recommendations as drawn up in 1890 worked well, as shown by the results of many collisions between vessels so subdivided. The case of the *Titanic* was an exceptional case and one never likely to happen again when so many compartments were cut open to the sea by collision with an iceberg. These recommendations by the British Bulkhead Committee were adopted by the German Government.

By referring to the United States Statute 4490:

"Every seagoing steamer, and every steamer navigating the great Northern or Northwestern lakes, carrying passengers, the building of which shall be completed after the twenty-eighth day of August, eighteen hundred and seventy-one, shall have not less than three watertight cross-bulkheads, such bulkheads to reach to the main deck in single-decked vessels, otherwise to the deck next below the main deck; to be made of iron plates, sustained upon suitable framework; and to be properly secured to the hull of the vessel. The position of such bulkheads and the strength of material of which the same shall be constructed shall be determined by the general rules of the board of supervising inspectors."

Then when we refer to the general rules and regulations prescribed by the board of supervising inspectors—Rule III, paragraph 31—we find a new rule added, evidently influenced by the *Titanic* disaster, and not even conforming to the recommendations made in 1890 by the British Bulkhead Committee to which the *Titanic* was built:

"Every seagoing steam vessel, and every steam vessel navigating the great Northern and Northwestern lakes, constructed after July 1, 1912, carrying passengers, shall have a watertight collision bulkhead. In vessels not over 200 feet in length this bulkhead shall be located about one-tenth the vessel's length from stem. In vessels over 200 and not over 300 feet in length the collision bulkhead shall be located about one-twelfth the vessel's length abaft the stem. In vessels over 350 and not over 500 feet in length it shall be located about one-fifteenth the vessel's length abaft the stem, and in vessels over 500 feet in length, about one-sixteenth the vessel's length abaft the stem. Such vessels shall also have one watertight bulkhead forward of and one abaft the engine and boilers, and, in addition thereto, shall have such other watertight bulkheads as may be necessary to provide that there shall be no space between the bulkheads to exceed in length one-fifth the length of the vessel: *Provided,* however, That in no case shall the distance between the bulkheads be greater than 80 feet.

" Screw steamers shall, in addition to the above-mentioned bulkheads, have located at a suitable distance forward from sternpost a watertight bulkhead to protect vessel from disaster in case of fracture of stern pipe.

" All such bulkheads shall be of iron or steel plates not less than ¼ inch thick, and shall be securely fastened to suitable framework, which framework shall be properly and securely attached to the hull. Such bulkheads shall be strengthened by vertical bars of not less than 3½-by-3½-inch angle iron, spaced not more than 30 inches from centre to centre, and all steamers that are more than 10 feet deep in any hold shall have horizontal angle irons of not less than 3 by 3 inches on the reverse side, spaced not more than 4 feet from centre to centre, in addition to the vertical angle irons.

"*Provided,* That when any bulkheads are constructed of equal strength to the above-described bulkheads, they shall be allowed by the local inspector.

" All bulkheads shall reach to the main deck in single-decked vessels, otherwise to the deck next below the main deck, but in every case they shall reach to the deck next above the deep load line."

The rule specified under this paragraph 31 is open to very much criticism, as it does not ensure that all vessels built to this rule will float if any two adjacent compartments were flooded.

The paragraph specifying the scantlings of bulkheads is altogether inadequate for bulkheads required to withstand a high pressure of water after the vessel is flooded.

The paragraph specifying the height of bulkheads is not definite enough, as the main deck of a vessel is not specified anywhere in the statutes or rules, and a deck might be taken as the main deck that would not ensure safety after flooding the compartments. The latter part of this paragraph saying that " in every case the bulkheads shall reach to the deck next above the deep load line " is not definite enough, as the " deck next above the deep load line " may only be a few inches above the deep load line.

Evidently considerable thought has been given to the subdivision by bulkheads, but why not consider such an important subject carefully and have a committee of experienced shipowners and shipbuilders appointed by the Government to draw up the necessary regulations?

The subdivision of the vessel by watertight bulkheads, the construction of the bulkheads, and the fitting of double bottoms should be carefully considered, as it is necessary to safeguard the large number of passengers carried on steamers on the Atlantic and Pacific coasts.

It would astonish you and the public to know what would happen to the majority of the passenger steamers running on the Atlantic and Pacific coasts if two of them collided. It is surely not necessary to wait till there is a great loss of life before this question is taken up seriously and the rules amended.

Referring to Rule III, paragraph 31, quoted above, it is not clear that ferry-boats or river steamers such as run in New York Harbor, San Francisco Bay, or the Chesapeake require to have watertight bulkheads for safety. These vessels may be in collision in a fog, say between the Battery and Staten Island, on the Hudson River, or between Oakland and San Francisco, and if divided up so that they would float with any two compartments flooded a great loss of life might be averted.

The author of this paper made suggestions in February, 1905, to the Board of Supervising Inspectors as regards the safety of life at sea, and drew up rules for life-boats, freeboard, watertight subdivision, etc. A great many of these suggestions have been incorporated in the rules, but a considerable number of important rules has yet to be adopted. The recommendations made regarding bulkheads at that time are again made and are as follows:

"It is suggested that United States vessels be graded as herewith described:

"The following vessels shall be subdivided as described for Grade No. 1:

"Passengers and mail vessels navigating the ocean with limited freight only.

"All other passenger vessels navigating the ocean over 425 feet long.

"Passenger vessels on the Great Lakes and coast with limited freight only.

"Passenger vessels making short passages on the sea.

"Sound passenger vessels.

"Ferry-boats carrying passengers.

"Ferry-boats carrying passenger trains.

"Excursion vessels on estuaries and bays.

"River vessels carrying passengers and limited freight only.

"In connection with the above the following explanations are necessary:

"Limited freight shall mean an amount of freight, exclusive of passengers' baggage, not exceeding 25 per cent. of the gross registered tonnage in tons of 2,240 pounds each.

"The vessels described above shall be subdivided to float with any two compartments flooded, irrespective of their length.

"It is impossible to give the exact location of the bulkheads in actual measurements; in order to enable inspectors to perform this part of their duty, it will be necessary to work out series of curves of tabulated data to enable them to decide the proper location in each case.

"These curves will vary with several conditions, the principal being the density of the cargo and the height of the bulkhead deck above water. An average density of cargo will have to be assumed and corrections made for varying freeboards, all of which can be readily embodied in the curves referred to.

"All vessels of 350 feet length and less than 425 feet, carrying passengers and not falling under paragraph above, shall be subdivided so as to float in moderate weather with any two adjoining forebody compartments open to the sea.

"All vessels of 300 feet length and less than 350 feet, carrying passengers and not falling under Grade No. 1, shall be subdivided so as to float in moderate weather with any adjoining two of the three foremost compartments, or with any one of the other compartments, open to the sea.

"All vessels under 300 feet, carrying passengers and not falling under Grade No. 1, shall be subdivided so as to float in moderate weather with the two foremost, or any one of the other compartments, open to the sea.

"All freight vessels navigating the ocean and Great Lakes shall have a collision bulkhead forward, an after peak bulkhead (except when the machinery is fitted right aft), and a bulkhead at each end of the machinery space.

"This rule is suggested because a closer subdivision would be detrimental to legitimate business interests; the close subdivision required for passenger vessels would in many instances, notably on the Great Lakes, practically kill all water carrying on a large scale. The registry societies prescribe certain bulkheads in vessels classed with them, the effect of these bulkheads being merely to delay a vessel foundering and not to make her unsinkable.

"The life-saving appliances prescribed in rule for life-boats are sufficient to care for the crew in the event of accident, and it is not necessary to do more, as by their calling they are more inured to hardship than the passengers.

"All vessels carrying freight only and not accounted for under above paragraph shall have a collision bulkhead forward.

"It is suggested that a table showing the limits of the different classes of navigation be drawn up for use in the administration of these rules and requirements, as it is practically impossible to make a general statement to meet all classes. This table is needed particularly to meet the case of vessels making voyages partly in rivers and partly at sea along the coast."

List of casualties (only those considered serious), as reported by the Steamboat Inspection Service:

		Lost lives.
1905.	Steamship *Peconic,* foundered off Florida coast	20
	Loss of steamship *Sevona* on Lake Superior	7
	Loss of steamship *Iosco* on Lake Superior	19
	Steamship *Valiyuga,* foundered in Lake Huron	17
	Steamship *Ira H. Owen,* wrecked in Lake Superior	19
	Steamship *Mataafe,* stranded near Duluth	9
1906.	Steamship *Valencia,* wrecked, Vancouver Island, B. C.	121
	Collision, steamship *Dix* and steamship *Jeanie,* Puget Sound	42
	Steamship *W. T. Scovall,* Vicksburg, Miss., boilers exploded	10
1907.	Steamship *Marion,* South Carolina, steamer burnt	12
	Steamship *Arcadia,* foundered on Lake Michigan	11
	Collision, steamship *Larchmont* and schooner *Harry Knowlton,* Block Island Sound	133
	Larchmont was damaged at fireroom, sank in less than ten minutes, only a few got away in the life-boats.	
	Collision, steamship *Columbia* and *San Pedro,* Shelter Cove, Cal.	86

	Steamship *Cypress,* foundered in Lake Superior, heavy gale	22
	Steamship *Miriam,* on Mississippi River, struck by cyclone	11
1908.	Steamship *H. M. Carter,* on Mississippi River, boilers exploded, ship took fire	11
	Steamship *D. M. Clemson,* foundered Lake Superior, severe storm	24
1909.	Fishing steamship *Geo. A. Floss,* sank in gale	7
	Tug *Eagle* capsized	8
	Steamship *Adelle Shores,* foundered in gale	8
	Collision, steamship *John B. Cowle* and *Isaac M. Scott,* Lake Superior	14
	John B. Cowle sank in three minutes.	
	Steamship *Clarion,* Lake Erie, took fire, 1 lost in fire, 14 lost in life-boat	15
	Steamship *Marquette* and *Bessemer No. 2,* never heard of	30
1910.	Steamship *Czarina,* foundered Coos Bay Bar	24
	Steamship *City of Saltillo,* St. Louis, Mo., struck rock in Missouri River and sank	12
	Steamship *Frank H. Goodyear* and *James B. Wood,* in collision, Lake Huron	18
	Steamship *Pere Marquette No. 18,* Ludington, Mich., to Milwaukee, Wis., sank	27
	Steamship *Arkadia,* New Orleans to San Juan, P. R.	37
1911.	Three coal barges wrecked on Cape Cod	17
	Steamship *City of St. Joseph,* Mississippi River, boiler explosion	22
	Thirty casualties	819

Report	LIVES LOST.						
	Fire	Collision	Explosions or accidental escape of steam	Break of steam pipes, etc.	Snags, wrecks, and sinking	Miscellaneous	Total
1911	10	46	42	..	114	69	281
1910	21	61	12	6	119	41	260
1909	3	37	9	7	68	73	197
1908	12	129	6	..	71	59	277
1907	31	193	27	3	55	63	372
1906	6	45	12	3	253	54	373
1905	14	35	14	..	33	41	137
Totals	97	546	122	19	713	400	1897

During the years 1905–1911, when there was reported a loss of life of 1,897 persons from fires, collisions, explosions, wrecks, sinking, and miscellaneous, there is no doubt that if rules regulating the freeboard and subdivision had been in force there would have been a further great saving of life.

LIFE-BOATS AND BUOYANT APPARATUS.

Up till January, 1912, the rules of the United States Steamboat Inspection Service required a life-boat scale based on the tonnage of the vessel, similar to that in force in the British rules. On March, 1912, a new rule was made by the United States Steamboat Inspection Service that all steamers navigating the ocean must be provided with sufficient life-boat capacity to accommodate every person on board, including passengers and crew. This is an excellent rule, but has not been in operation long enough to effect much result.

As regards other steamers, the life-boats required were specified according to tonnage. In July, 1912, the following rules were passed regarding the life-boats required:

"All steamers other than steamers carrying passengers, except as otherwise hereinafter provided for, must be equipped with life-boats of sufficient capacity to accommodate at one time all persons on board. One-half of such equipment may be in approved life rafts or approved collapsible life-boats.

"Ocean steamers carrying passengers must be equipped with life-boats of sufficient capacity to accommodate at one time all persons on board, including passengers and crew. One-half of such life-boat equipment may be in approved life rafts or approved collapsible life-boats.

"Coastwise steamers carrying passengers must be equipped with life-boats of sufficient capacity to accommodate at one time all persons on board, including passengers and crew: *Provided,* however, That such steamers navigating during the interval from the 15th day of May to the 15th day of September in any one year, both dates inclusive, will be required to be equipped with life-boats of only such capacity as will be sufficient to accommodate at one time at least 60 per cent. of all persons on board, including passengers and crew; two-thirds of such required life-boat equipment throughout the year may be in approved life rafts or approved collapsible life-boats.

"Lake, bay, and sound steamers carrying passengers must be equipped with life-boats of sufficient capacity to accommodate at one time all persons on board, including passengers and crew:

Provided, however, That such steamers navigating during the interval from the 15th day of May to the 15th day of September in any one year, both dates inclusive, will be required to be equipped with life-boats of only such capacity as will be sufficient to accommodate at one time at least 30 per cent. of all persons on board, including passengers and crew: *Provided,* further, That such steamers navigating routes lying at all points within a distance of 5 miles from land, or over waters whose depth is not sufficient to entirely submerge the vessel in case of disaster, will, during the interval from the 15th day of May to the 15th day of September in any one year, both dates inclusive, be required to be equipped with life-boats of only such capacity as will be sufficient to accommodate at one time at least 10 per cent. of all persons on board, including passengers and crew. Three-fourths of the life-boat equipment required on lake, bay, and sound steamers may be in approved life rafts or approved collapsible life-boats.

"River steamers carrying passengers must be equipped with life-boats of sufficient capacity to accommodate at one time at least 10 per cent. of all persons on board, including passengers and crew. Three-fourths of such life-boat equipment may be in approved life rafts or approved collapsible life-boats."

The above rules appear to be sufficient as regards life-boats and rafts, but additional buoyant apparatus in the form of seats, etc., should be fitted in coastwise, lake, bay, sound, and river steamers and ferry-boats carrying passengers, so that there is buoyant apparatus for all on board all the year round.

As regards ferry-boats in services mentioned, buoyant tanks could be fitted which, together with the life-boats, would accommodate all on board, and these buoyant tanks could be stowed on top of the deckhouse. As regards large passenger steamers on sounds and rivers, deck seats on uppermost decks could be made buoyant and able to float off in case of accident.

The question of launching buoyant apparatus is a large one and would require careful investigation so as to suit all the conditions and services.

It is hoped that the information given in this paper will help and influence the proper authorities to take up the important question of "Safety of Life at Sea," with special reference to the construction and watertight subdivision of vessels and life-saving buoyant apparatus and the launching of the same. Technical committees should be appointed by the Government to investigate and suggest regulations that may be enacted into law. It was in expectation of this being done that I took the liberty to place before the members of this Institute this important subject of the " Safety of Life at Sea."

Discussion.

Mr. G. W. Dickie, Naval Architect: Mr. Chairman: Although I have been many years a member of the Institute, this is the first meeting I have been able to attend. I am pleased to have the opportunity to speak on this very important subject, which has been presented to you in an able manner, both practically and historically, by my friend, Mr. Donald. There is nothing that I could add to the historical part of the paper, which part shows the difficulties connected with providing sufficient means of saving lives when a great passenger steamship has been mortally wounded by any accident that destroys the integrity of her hull.

It is unfortunate that the case of the *Titanic,* a case never before occurring and unlikely to occur again, should be used as the basis for a great deal of unwise legislation in regard to life-saving equipment. The inquiry should have been directed principally to the possibility of so improving the structure of the vessel as to render the need of life-saving apparatus a contingency much more remote than it is at present.

In looking at the plans of the *Titanic* it appears to me that ultimate safety was sacrificed to the convenience and comfort of the passengers. For instance, the transverse bulkheads forward of the engine-room enclosure were one deck lower than those aft. The reason for this is apparent when the bulkheads are considered in connection with the passenger accommodations.

The bulkhead question has always been a compromise between safety in case of an accident which may never happen and the everyday problem of working the ship and the everyday comfort of the passenger. The only absolutely safe bulkhead is the bulkhead that has no opening in it, and I am sure that a ship so built would not be popular among the passengers on the lower passenger decks, while the problem of fore and aft communication between the engine- and boiler-rooms would not be easily solved.

A double skin without openings in the inner skin may yet be found to be the simplest solution. Whatever the answer may be to this problem, however, the safety of the ship herself should have first consideration, for with the ship safe, all the life-saving problems are settled.

Mr. Robert Haig, Surveyor, Lloyd's Registry of Shipping, Philadelphia: The question of "Safety of Life at Sea" is of the deepest concern to shipbuilders and owners, as it is also to those who travel in ships.

One has only to consider the efforts continually being made by both builders and owners to devise or develop such arrangements that will tend to give the vessel greater protection or stability in times of stress such as we have recently witnessed in the lamentable catastrophe to the steamship *Titanic.*

In a calamity such as the *Titanic,* the first impression is that there should be a greatly-increased number of life-boats, sufficient to take care of the entire passengers and crew, which in this vessel might have amounted to 3000 people, and, with an allowance of 50 people per boat, would mean that the vessel would require to be equipped with 60 boats, a number it would be impossible to handle in times of trouble and almost as difficult to find room on the deck of the vessel to stow the boats.

While it is possible some lives that were lost on the *Titanic* might have been saved if there had been more boats, it is a fact that is quite well known that many more lives would have been saved if the people could have been induced to get into the boats that the vessel was equipped with.

That the mishap to the *Titanic,* from a structural point of view, was almost impossible to guard against is amply borne out by the fact that, while the vessel was holed right forward, the extent of the damage in a fore aft line was sufficiently great to allow water to enter the machinery space, and it is hardly possible that any arrangement of bulkheads could have kept the vessel afloat with the hull plating pierced in so many of the holds. There is no record that the bulkheads gave way, and there is every reason to feel confident they did not. Bulkheads are designed and constructed on well-established data deduced from exhaustive experiment and investigation, and wide experience has demonstrated that when well constructed they are sufficiently strong for the duty they have to perform and there is no doubt that in a type of vessel like the *Titanic* all of the work was of a high order. Experience would seem to indicate that in large, high-speed vessels when so much is at stake, the extra cost of extending the double bottom (or inner skin) up to or near the water line does not become nearly so important a factor as the greater security obtained.

No doubt, further subdivision by additional transverse or longitudinal bulkheads in large passenger or cargo vessels will be required at an early date, as there are many able brains working on the subject at the present time, and papers such as the one we are now discussing will serve a most useful purpose in assisting the development of this subject.

Naval Constructor Elliott Snow: It is generally conceded by naval architects that the most effective step toward securing the safety of life at sea lies in applying in a practical way the old adage " An ounce of prevention is worth a pound of cure " ; in short, in making the vessel itself as safe as possible, and thereby reducing to the very lowest limit the chance of having to resort to the life-saving equipment of the vessel.

This view is entertained because it is known and recognized that even with the most modern equipment of life-boats and safety appliances it is a very difficult and dangerous operation to lower a boat in any other than a comparatively smooth sea and during daylight hours.

As the subject dealt with in the paper was too large to permit of its being dealt with *in extenso,* the author has very wisely limited himself to a general outline only, and has dealt more particularly with the question of watertight subdivision and life-saving appliances,—that is, life-boats and other buoyant apparatus.

I heartily concur with the view expressed, that the subdivision of the vessel by watertight bulkheads, decks, and double bottoms should be more carefully considered. U. S. Statute 4490, which prescribes bulkheads for certain classes of vessels, is clearly defective, and the rules that have been promulgated thereon are inadequate to provide for the safety of a vessel at sea as regards her watertight subdivision. The law is defective in that it is too limited in its requirements and it attempts irrelevant detail. The rules are inadequate in that they do not insure that all vessels built under those rules will float if any two adjacent compartments were flooded. *This requirement that a vessel will float with two adjacent compartments flooded should be required as a minimum.*

Summing up in a slightly different form from that given by the author, it appears that the safety of the vessel would best be promoted by careful attention to

(1) The design of the vessel;
(2) The construction of the vessel;
(3) The equipment of the vessel;
(4) The operation of the vessel;

the design, construction, and equipment being subject, of course, to careful inspection, and the operation also subject to inspection and further control by public opinion.

I think it would be unwise to enact further legislation until the whole subject of the watertight subdivision of vessels, both sea-going, those on the Great Lakes, and on the bays and inland waters, is given consideration by a board of experts. The deliberations of such a body would be materially assisted by consulting the records of the British Bulkhead Committee, drawn up in 1890, and the personnel of such a body of experts could be easily drawn from the members of the American Society of Naval Architects and Marine Engineers.

Mr. Ernest H. Rigg, Naval Architect, New York Shipbuilding Company: The history of legislation on this subject, when read between the lines, shows a natural hesitancy on the part of individual nations to enact laws that will handicap their own merchant marine in competition with that of other nations; for example, the British Freeboard Regulations have only been slowly adopted in the other countries and not even yet by this country: not that we should slavishly adopt any regulations, providing we enact equivalents of our own, but this even has not been done.

The numerous international congresses which have been necessary to bring about practical uniformity in tonnage measurements of ships again show the difficulties of the question.

Since the loss of the *Titanic,* Great Britain and Germany have both been busy setting their houses in order. Everywhere, however, including America, too much attention has been concentrated on life-boats; the *Titanic* went down in a calm sea and the boats were effective; how many disasters have happened in weather too severe for boats to be launched and gotten away from the ship's side? What is wanted is such subdivision of passenger ships as will make them practically unsinkable; but this must be international to be effective. Great Britain, in her freeboard legislation, made a great business sacrifice for humanity's sake: she led the way, and gradually most of the leading maritime states have followed.

It is not to be expected, in the face of modern competition, that she will do it again on bulkheads.

Railroad regulation is a national affair, and therefore more easily handled; on the high seas all are equal, and therefore international agreement on regulations is necessary. Great Britain has a Bulkhead Committee again at work, and doubtless Germany is working on the same subject; are we? Enlightened and definite action on the part of the Secretary of Commerce and Labor is needed, looking toward the framing of regulations which will provide for safety at sea without arbitrarily imposing unnecessary handicaps on sea-borne commerce. Severe collisions have occurred and will occur again; there is no reason why they should be attended with unnecessary loss of life.

Wireless telegraphy helps greatly, but it is nothing but a trap, if the ships can't stay afloat till help comes.

The science of naval architecture is a vastly different thing to-day compared with even thirty years ago; steel has supplanted more difficult and less adaptable materials of construction, and ships have benefited greatly in the general engineering progress that has been made.

The *Great Eastern* survived as bad a smash as the *Titanic,* and that was sixty years ago. Battleships have done the same, size for size.

To make passenger ships more secure will cost money, and no individual nation or firm can undertake to bankrupt itself by going too far ahead of international regulations; but enlightened public opinion demands better ships than the *Titanic,* even at a fractional increase in the rate of fare to cover a higher standard of construction, and even if some of the latest elaborations of swimming pools and gymnasia are to be dispensed with.

The rates on the big, fast Cunarders are higher; it would be interesting to know how much is due to increased speed and how much to the increased safety, subsidized naval auxiliaries though they are; they command the confidence of the public, and consequently their patronage.

When quoting these large Cunarders and German ships it must always be remembered that they are subsidized as naval auxiliaries and could not get that subsidy without the subdivision that renders them so safe.

Mr. Donald's paper is a very painstaking presentation of the case, and the Institute is to be congratulated in being on record as interested in this great subject. It is to be regretted that we as a nation have not gone into the question in the same thorough manner as others, because it is poor sport following where others lead. The army authorities are conducting some investigations on life-saving appliances with a view to finding something of value for the Philippine transports.

The other gentlemen who have taken part in this discussion brought out many interesting points. In conclusion I should like to emphasize:

First.—The necessity for better bulkhead regulations in passenger-carrying vessels. This embraces the whole subject of subdivision, both vertical and horizontal.

Second.—The necessity for better boat provision than has been allowed in the past.

Third.—A general overhauling and modernizing of the regulations covering methods of communication, the state of development of which is advancing rapidly.

Fourth.—Manning regulations and conditions that will attract a good class of men as crew for passenger ships.

Fifth.—Increased steering and manœuvring power for merchant shipping.

Sixth.—The large ship has come to stay, and is more immune from disaster than the small one.

Seventh.—As evidence of the progress of the times, Lloyd's Register have recently completely revised and rewritten their regulations for building ships.

Eighth.—The subject of stability is well understood these days, and is not the bugaboo it was thirty years ago.

Ninth.—Experimental model tanks enable ships to be driven with less power for the same speed than was formerly the case. This saving could well go into bulkheads.

Tenth.—Fire protection on liners should receive better attention. The large German vessels are good examples in this way.

Eleventh.—Marine engineers can now produce a horse-power with less coal than formerly; could not some of this saving go into safety?

To summarize the whole thing, let shipping receive the benefit of modern scientific progress and development: not partially, but wholly.

New Method of Insulating Windings of High-voltage Machines. K. PERLEWITZ. (*Electrotechn. Zeitschr.*, xxxii, 1028.)—This article describes the method used by the firm of E. Haefely, of Basel, in which Highfield's ideas are carried out. The air spaces between wires are completely filled to the exclusion of air by means of compound, and the coil is then wrapped with several layers of a foil termed "Micarta Folium," consisting of paper, mica, and enamel; the whole coil is then placed in a special machine, which is described, and compressed. The insulation is stated to be so good that a 3 mm. thickness will stand 65,000 to 70,000 volts if in separate wires, and 80,000 to 85,000 if formed of a single conductor.

The Choice of a Frequency. D. B. RUSHMORE. (*Amer. Inst. Elect. Engin.*, xxxi, 787.)—This article deals with the effects produced by the choice of a frequency on the lay-out and efficiency of a central station or power transmission scheme. The following points are considered, viz.: generators, transformers, transmission lines, lightning, induction motors, synchronous motors, frequency changers, railway work, switching phenomena, and illumination. The paper concludes with a list of frequencies used in many stations in the United States; and these frequencies are always either 25 or 60.

INDUSTRIAL FELLOWSHIPS: FIVE YEARS OF AN EDUCATIONAL INDUSTRIAL EXPERIMENT.[1]

BY

ROBERT KENNEDY DUNCAN, Sc.D.,

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Some six years ago, at the meeting in Rome of the International Congress of Applied Chemistry, I thought out what appeared to be a sane, practical scheme of relationship between industry and learning for the purpose of promoting the increase of useful knowledge. As this scheme in its essentials is identical with that which I have since been privileged to realize in fact, the fundamental basis on which it was elaborated ought first to be presented.

Industry.

(1) At that time, generalizing as much as one may, American Industry, from the standpoint of efficiency and of progressive factory practice, was in a lamentable condition. The reasons for this condition were plainly evident:

(*a*) The existence of a high tariff which, whether good or ill for the people as a whole, certainly injured the efficiency of American manufacture by shutting out the competition of the efficiency of foreign manufacture working through the application of modern science.

(*b*) The creation of combinations for the elimination of competition and the consequent substitution of business intrigue for manufacturing efficiency.

(*c*) The existence of large stores of raw materials everywhere available.

(*d*) The needs of a rapidly-expanding population.

(*e*) The evolution of an area of extravagance in purchasing.

(*f*) An enormous development of the business of lying advertisement.

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[1] Presented at the meeting of the Section of Physics held Thursday, October 3, 1912.

It was obvious, even then, that the American manufacturer resting upon such factors for success was in a precarious position, and that with the inevitable passing of such factors he could expect to survive only on a basis of efficiency.

Learning.

(2) But this efficiency, which means the conservation of waste, the bettering and cheapening of the products manufactured and the discovery of new and useful products to the manufacturer concerned, was not easily come by.

It could enter the factory only through the employment therein of men of high scientific and technical training, working in an atmosphere conducive to success—men who were genuine researchers inspired to solve practical problems. The universities of the country were not providing the industries with men of such qualities. It is true that they were sending out large numbers of men—chemical engineers, etc.—on the basis of a four years' college course, but such men were merely *taught* men; they were not researchers, and under the conditions of contemporary factory practice were deprived of the possibilities of development, and were, in fact, for the purposes of research merely ruined. The genuine researchers turned out by the universities, young doctors of philosophy with a record of successful academic research and with a proved capacity for creative work, were discouraged by the universities of any ambition to enter applied research and were led to consider the teaching profession as the only logical goal. A man of splendid training and of brilliant research qualifications who entered applied science—among whom are the few contemporary first-class research technologists—did so under the onus of academic disapproval. The reason for this lay in the fact that American science had through generations been built upon the basis of severe academicism and formalism. It was deemed contrary to university ideals and traditions that research should have in view any utilitarian end; there was great insistence upon *pure* science, the implication being that applied science was *im*pure and constituted a degraded form of research.

I am aware, of course, that I am discoursing very largely in this matter, but, making all due exceptions, the essential truth of these statements can hardly be a matter for dispute.

From the standpoint of applied science and for the immediate future, with its radically changing conditions, industry, then, was in a deplorable way, and learning, as represented by its leading universities, both in spirit and in power, was little to be depended upon for serviceable help.

Under the circumstances, then, there seemed to be desirable some form of co-operation between industry and learning, so arranged that it might stand as a permanent relation.

Such an arrangement as originally presented by the writer may be found as the last chapter of "The Chemistry of Commerce" (Harper's). It was based upon a definite form of agreement between a manufacturing company and a university, providing for the establishment in the university for a period of two years, on the part of the company, of an "Industrial Fellowship"—the researcher concerned in this work being termed a Fellow.

Since the original presentation of this scheme, the agreement upon which it was founded has been discussed and argued back and forth through the offices of so many companies that while identical, in its main provisions, with its prototype, in its details it has become modified to correspond with what was learned as the development of the scheme proceeded.

In order to give the reader a clear idea of what I now regard as a reasonable relation for all concerned, I shall insert in this place, and for the first time, the agreement of an Industrial Fellowship which has recently been established at the University of Pittsburgh.

(Form of Multiple Fellowship.)

———— COMPANY'S INDUSTRIAL FELLOWSHIP AGREEMENT.

For the purpose of promoting the increase of useful knowledge, the University of Pittsburgh accepts from ———— COMPANY, having head-officers at ————, the foundation of a Multiple Industrial Fellowship, to be known as the ———— COMPANY'S FELLOWSHIPS.

It is mutually understood and agreed that the conditions governing this Multiple Fellowship shall be as follows:

The exclusive purpose of this Fellowship is ————————————

————————————————————————————————

such problems to be stated by the Company in a separate memorandum to the Director of Industrial Research and acquiesced in by him.

To the furtherance of the problems of this Fellowship, the holders thereof shall give their whole time and attention, with the exception of three hours a week, which each shall give to instructional work in the University.

The Fellows shall work under the advice and direction of the Director of Industrial Research, and they shall forward periodically, through the Director of Industrial Research, reports of the progress of their work to ——— COMPANY.

The Fellows shall be nominated by the Chancellor of the University and the Director of Industrial Research to the Board of Trustees of the University, which Board may appoint them to their respective positions in accordance with the terms of their formal letters of application to the Chancellor as approved by the Director of Industrial Research. They shall be provided with a separate laboratory and all supplies, reagents, etc., which might reasonably be expected to be in the possession of a large University, for the cost and payment of which their instructional services shall be taken in lieu. The donating company, on its part, undertakes to co-operate with the University in this research by providing the Director of Industrial Research and the Fellows of this Fellowship with its sympathy and with whatever knowledge of the subjects of research it may possess, and, on approval of the company, with its factory facilities for large-scale experimentation.

For the support of this Fellowship, which shall extend through a period of Two Years, ——— COMPANY agrees to pay FIVE THOUSAND DOLLARS ($5,000) per year to the University ANNUALLY IN ADVANCE ON ——— OF THE YEARS ———. All money paid in by ——— COMPANY under this Agreement shall be paid over by the University in monthly instalments to the holders of this Fellowship in such amounts as may be agreed upon by contract between the University and the Fellows concerned and, as well, on the order of the Director of Industrial Research, for such special apparatus related to this research as he may deem it advisable to purchase and for travelling expenses related to the elucidation of the problems concerned. On or before the expiration of this Fellowship the business services of any or all of the Fellows of this Fellowship may be secured by the donating company for a period of three years, on condition that the terms for such services are satisfactory to the parties at interest.

In the event that any money paid to the University in behalf of this Fellowship remains unexpended on the termination of the Fellowship, it shall be returned forthwith to ——— COMPANY.

Any and all discoveries made by the Fellows during the tenure of this Fellowship, as well as all information obtained by them germane to the subjects of their investigation, shall become the property of ——— COMPANY. But it is understood and agreed that the donating company obligates itself to pay to these Fellows considered collectively a maximum

CASH BONUS OF $10,000, or any part thereof which, in the opinion of the Board of Arbitration provided for in this agreement, is deserved by these Fellows, and that this Board of Arbitration shall decide the time or times in its payment. It is understood and agreed, however, that the estimation of the actual amount of this bonus shall not be made until———

———————————————————————

The relative distribution of this bonus to the individual Fellows concerned shall be wholly within the power of the University to decide and determine.

In the event of any difference of opinion as to the interpretation of this Agreement, a Board of Arbitration is hereby provided for, which Board shall consist of a Representative of the University and a Representative of ——— COMPANY and a Third Person whom these two shall select. The decisions of this Board as to the interpretation of this Agreement shall be binding upon the parties at issue, and they shall obtain such decision before having recourse to the courts.

At any time during the tenure of this Fellowship, patents must be taken out at the option and expense of the donor, on condition that the patentee or patentees assign all rights to the donor under the conditions of this Agreement.

It is also understood and agreed that during the tenure of this Fellowship the holders may publish such results of their investigations as do not, in the opinion of the donating corporation and as acquiesced in by the Director of Industrial Research, injure its interests, and that on the expiration of the Fellowship the holders thereof shall have completed a comprehensive monograph on the subject of their research, containing both what they and others have been able to discover. A copy of this monograph shall be forwarded to ——— COMPANY, and a copy shall be signed and placed in the archives of the University until the expiration of three years from that date, when the University shall be at liberty to publish it for the use and benefit of the public. In the event that in the opinion of the donating corporation publication three years after the termination of the Fellowship would unduly injure its interests, it is at liberty to appeal for an extension of time to the Board of Arbitration provided for herein, which, after consideration of this appeal, is at liberty to extend the time of publication to a period which, in its belief, conserves the interests of all concerned.

DATED:
SIGNED ON
BEHALF OF ——— COMPANY.

DATED:
SIGNED ON
BEHALF OF UNIVERSITY OF PITTSBURGH.

A careful reading and re-reading of this agreement will make it evident that it relates to four different factors, and the degree to which it harmonizes with these different factors determines its acceptability and its chance of becoming a permanent relation.

These factors are:

(*a*) The University.
(*b*) The Company.
(*c*) The Public.
(*d*) The Researcher or Researchers engaged.

(*a*) *The University.*

The University is fulfilling its function in increasing the sum of knowledge; the fact that it is useful knowledge does not make it any the less valuable. Furthermore, the right to publish such knowledge is assured to the University under the agreement. An additional advantage lies in the large teaching force which, in accordance with the agreements, is provided for gratuitous instructional service in teaching chemistry. Still another advantage to the University lies in the relation of this system to its graduate school. Many of the " Fellows," as they are called, already hold graduate degrees; others, junior Fellows, hold Fellowships which are advisedly provided for young men who have just graduated from their college and who are men of promise. They are carefully chosen from the best universities and constitute, naturally, a strong element in a graduate school.

(*b*) *The Company.*

From the standpoint of the company, the system has gone past the experimental stage and now unquestionably constitutes a privilege; it has been demonstrated over and over that, working in accordance with this system, it is possible to accomplish results that cannot otherwise be obtained. And this is but reasonable.

The University is provided with an equipment for experimentation immeasurably larger than that in the possession of any but the fewest factory laboratories.

Equally important are library facilities, without which no research can progress. The University, as a matter of course, is in possession of the stores of past and contemporary scientific literature; factories, on the contrary, and with, let us say, half a dozen exceptions, are barren of such; factory sites are not placed with a view to library facilities, and yet the lack of such facilities is undoubtedly a contributing cause to the normal failure of factory research.

Still again, the University is in possession of large and important consultative facilities—mathematical, physical, engineering, bacteriological, etc.—and these are, of course, freely offered to the chemical researchers working under this system.

Finally, there is about university work, as differentiated from the factory, freedom from interference, correct judgments concerning progress, and an atmosphere sympathetic to research.

All these advantages, laboratory, library, consultative, and inspirational, together with the supervision and administration of these Fellowships, the University offers gratuitously to any company having important problems offering a reasonable chance of solution, and it undertakes, as well, to surround these researches with necessary secrecy.

(*c*) *The Public.*

The public is largely advantaged through this system. No discovery can go to the public as a useful actuality of achievement except through some company, or, to use what in these days, is an invidious term, some *corporation*. Corporations may be good or bad, or both, and the people of this country may be depended upon ultimately to take care that they are made subservient to the public good; but every useful and significant fact is a permanent good to the human race. Even to-day, if manufacturing waste were eliminated and full advantage were taken of significant contemporary discovery, shorter hours of labor would obtain and human need would vanish; in fact, it may be said that never until such a condition does obtain shall we pass out of our materialistic, neurasthenic civilization.

(*d*) *The Researchers.*

For the Fellows, the young men engaged in these researches, the opportunities are unique. If they do not already possess their Ph.D., they may proceed for it in the University, using as their dissertation such portion of their research as we may permit; they are provided with a stipend such as they can show that they deserve; they are given every opportunity for genuine achievement; and, what is more, a full recognition of such achievement; and, finally, if they succeed in a practical way, they are assured through their bonus of a substantial, material reward.

In 1906, on returning from Europe, I proceeded to the University of Kansas, and on January 29, 1907, I established there the first Industrial Fellowship, on the basis of an agreement very similar to that presented above. From that time on I have proceeded carefully and tentatively, learning as I went, to establish one after another of these researches.

In recognition of the progress and demonstrated value of this work as a whole, the University of Kansas two years ago constituted it a department by itself. The University has built almost a dozen laboratory rooms for the accommodation of the Fellows, and in recognition of the value of their instructional services has, through action by the Board of Regents, determined that every Fellow shall in his instructional work receive the titular professorial distinction which his Fellowship stipend warrants. The University has, as well, conferred the degree of Doctor of Philosophy on two of the junior Fellows as a result of their researches. In 1910 the University of Kansas authorized the writer, while retaining his full position in Kansas, to accept, as well, a similar position at the University of Pittsburgh, in order that these Fellowships might be established in the East as well as in the West. The University of Pittsburgh, for the purpose of carrying out the researches, has provided a temporary building, adequately equipped, and has provided the Director with an associate, Raymond F. Bacon, Ph.D., who has charge of the details of the investigations.

A full list of these Fellowships as so far established in both universities, together with the subjects of research, etc., is herewith appended.

UNIVERSITY OF KANSAS FELLOWSHIPS
IN
ORDER OF ACCEPTANCE BY UNIVERSITY OF KANSAS.

Fellowships marked * have been completed.

I. * *Laundering.*
  $500 a year for 2 years.
    Additional consideration 10 per cent. of net profits.
      Fellow: Fred. Faragher, A.B.
        January 29, 1907.

II. * *Diastase.*
$500 a year for 2 years (continued 3rd year).
10 per cent. of gross profits.
Fellow: Ralph C. Shuey, B.S. (U. of Kansas).
June 14, 1907.

III. * *Bread.*
$500 a year for 2 years.
Additional consideration.
Fellow: H. A. Kohman, A.B. (U. of Kansas).
April 27, 1908.

IV. * *Casein.*
$500 a year for 2 years.
10 per cent. of net profits.
Fellow: E. L. Tague, A.M.
April 27, 1908.

V. * *Petroleum.*
$1000 a year for 2 years.
10 per cent. of net profits.
Fellow: F. W. Bushong, Ph.D.
April 27, 1908.

VI. * *Enamel.*
$1300 a year for 2 years.
Fellows: A. J. Weith, B.S.
F. P. Brock, B.S.
September 10, 1908.

VII. *Glass.*
$1500 1st year; $1500 2nd year; $1500 3rd year; $1500 4th year.
10 per cent. of net profits.
Fellow: E. Ward Tillotson, Ph.D.
March 9, 1909. (Now in its fourth year.)

VIII. * *Cement.*
$1500 a year for 2 years.
Additional consideration.
Fellow: J. F. MacKey, Ph.D.
March 9, 1909.

IX. *Varnish.*
$1500 1st year; $2700 2nd year; $3900 3rd year.
Additional consideration.
Fellow: 1st year, L. V. Redman, Ph.D.
2d year, L. V. Redman, Ph.D., Senior Fellow,
A. J. Weith, B.S.
F. P. Brock, B.S.
November 10, 1909. (Now in its fourth year.)

X. * *Borax.*
$750 a year for 2 years.
Fellow: B. C. Frichot, B.S.
November 29, 1909.

XI. * *Ductless Glands of Deep-Sea Mammals.*
$1000 a year for 2 years.
Additional consideration.
Fellow: E. R. Weidlein, A.B.
March 1, 1910.

XII. * *Vegetable Ivory.*
$1500 a year for 2 years.
$2000 bonus.
Fellow: J. P. Trickey, A.B. (New Hampshire College).
June 3, 1910.

XIII. *Petroleum.*
$2750 a year for 2 years.
$5000 bonus.
Fellows: F. W. Bushong, Ph.D. (Senior).
J. W. Humphreys, B.S.
April 26, 1911.

XIV. * *Gilsonite.*
$750 a year for 1 year.
$2000 bonus.
Fellow: W. E. Vawter, B.S. (U. of Kansas).
April 26, 1911.

XV. *Fats, Hardening of.*
$1300 a year for 2 years.
49 per cent. interest.
Fellow: E. O. Rhodes (U. of Kansas).
September 19, 1912.

XVI. *Leather-Scrap.*
$1200 a year for 2 years.
10 per cent. interest.
Fellow: R. Phillips Rose, A.B. (U. of Ohio).
October 22, 1912.

XVII. *Copper.*
$1800 a year for 1 year, $500 apparatus fund.
Additional consideration.
Fellow: E. R. Weidlein, A.M.
November 11, 1912.

XVIII. *Copper.*
$1000 a year for 1 year.
Additional consideration.
Fellow: G. A. Bragg, B.S. (U. of Kansas).

UNIVERSITY OF PITTSBURGH FELLOWSHIPS
IN
ORDER OF ACCEPTANCE BY UNIVERSITY OF PITTSBURGH.

I. *Baking.*
$750 a year for 2 years.
Additional cash bonus of $2000.
Fellow: Wilbur A. Hobbs, A.B. (U. of Kansas).
November 30, 1910.

II. *Abatement of the Smoke Nuisance.*
$12,000 1st year; $15,000 2d year.
Additional consideration 49 per cent. collective interest.

Fellows: *Staff in Charge.*

R. C. Benner, Ph.D. (U. of Wis.) (Chief Fellow).
W. W. Strong, Ph.D. (Johns Hopkins), Physicist.
J. A. Beck, LL.B. (U. of Pittsburgh), Attorney.
H. H. Kimball, Ph.D. (Geo. Wash. U.), Meteorologist.
A. B. Bellows, B.S. (Mass. Inst. of Tech.), Engineer.
O. R. McBride, B.S. (Purdue University), Engineer.
A. F. Nesbit, B.S. (Mass. Inst. Tech.), Electrical Engineer.
J. J. O'Connor, Jr., A.B. (U. of Pittsburgh), Economist.
E. H. McClelland, Ph.B. (Lafayette College), Bibliographer.
J. F. Clevenger, M.S. (Ohio State U.), Botanist.
C. H. Marcy, Bacteriologist.
J. E. W. Wallin, Ph.D., Psychologist.

Advisory Staff.

Oskar Klotz, M.D., C.M. (McGill University), Senior Fellow.
E. W. Day, A.M., M.D.
W. C. White, M.D.
R. T. Miller, Jr., M.D.
W. W. Blair, M.D.
B. A. Cohoe, A.B., M.D.
S. R. Haythorn, M.D.
W. L. Holman, M.D.
E. B. Lee, Architect, Senior Fellow.
Richard Hooker, B.S.
C. T. Ingham.

Richard Kiehnel.
Carlton Strong.
K. K. Stevens, B.S.
November 30, 1910; revised, June 24, 1911.

III. *On the Relation of the Pots to Glass in Glass-Making and the Elimination of "Strea."*
$1500 a year for 2 years.
Additional cash bonus of $2000.
Fellow: Samuel R. Scholes, Ph.D. (Yale University).
January 25, 1911.

IV. *Baking* (Wholly Independent of but with Acquiescence of No. I).
$4750 a year for 2 years.
Additional consideration of $10,000.
Fellows: Henry A. Kohman, Ph.D. (U. of Kansas), Senior Fellow.
Charles Hoffman, Ph.D. (Yale University).
Alfred E. Blake, A.B. (New Hampshire College).
January 25, 1911.

V. *Glue.*
$1200 a year for 2 years.
Fellow: Ralph C. Shuey, B.S. (U. of Kansas).
February 3, 1911.

VI. *Soap.*
$1200 a year for 2 years.
Fellow: Paul R. Parmelee, B.S. (U. of Kansas).
February 3, 1911.

VII. *Utilization of Fruit Waste.*
$1000 a year for 2 years.
Additional consideration of $10,000.
Fellow: F. Alexander McDermott (Geo. Wash. University).
May 12, 1911.

VIII. *Composition Flooring.*
$1500 a year for 2 years.
1 per cent. of sales for 5 years.
Fellow: R. R. Shively, B.S. (Okla. A. and M. College).
August 15, 1911.

IX. *Crude Petroleum.*
$10,000 a year for 2 years.
Collective interest of 10 per cent.
Fellows: Benjamin T. Brooks, Ph.D. (U. of Göttingen), Senior Fellow.

Clinton W. Clark, M.A. (Ohio State University).
Lester Pratt, M.S. (New Hampshire College).
Hugh Clark, M.A. (Ohio State University).
Arthur H. Myer, A.M. (Leland Stanford, Jr., University).
Fred. Padgett, B.S. (U. of Pittsburgh).
September 22, 1911.

X. *Natural Gas.*
$4000 a year for 2 years.
5 per cent. of industrial results.
Fellows: R. H. Brownlee, Ph.D. (University of Chicago), Senior Fellow.
Roy Uhlinger, M.A. (U. of Pittsburgh).
September 22, 1911.

XI. *Cement.*
$1800 a year for 2 years.
$10,000 additional consideration.
Fellow: J. F. MacKey, Ph.D. (University of Toronto).
September 22, 1911.

XII. *Foods, Problems Related to the Manufacture of.*
$5000 a year for 2 years.
$10,000 additional consideration.
Fellows: Clarence C. Vogt, Ph.D. (Ohio State University), Senior Fellow.
Harry P. Corliss, B.S. (New Hampshire College).
W. E. Vawter, B.S. (U. of Kansas).
May 20, 1912.

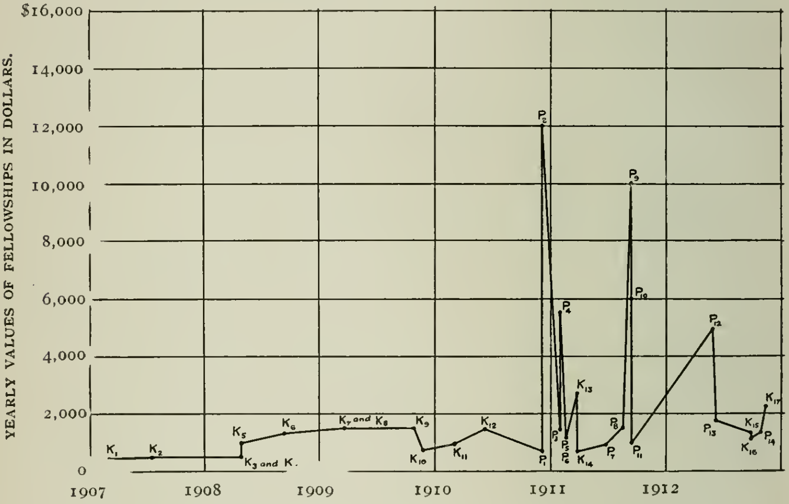
XIII. *Fats and Oils, Bleaching of.*
$1800 a year for 2 years.
Fellow: Leonard M. Liddle, Ph.D. (Yale University).
May 22, 1912.

XIV. *Effect of High Potential Electricity on Chemical Reaction.*
$1000 a year for 2 years; $300 apparatus fund.
Additional consideration.
Fellow not yet appointed.
October 28, 1912.

XV. *Discovery of Methods of Coating Steel or other Metals with Copper or other Metals.*
$1500 a year for 1 year; $500 apparatus fund.
Additional consideration $10,000.
Fellow: C. L. Perkins, B.S. (New Hampshire College).
December 4, 1912.

XVI. *Copper, Extraction of from its Ores and from Copper "Tailings."*
$1500 a year for 1 year.
Teaching Fellow: Howard D. Clayton, B.A. (Ohio State University).
December 1, 1912.

A reading of the list above will make obvious the consistent and accelerated growth of this system, as will the following diagrammatic representation.



DIAGRAMMATIC REPRESENTATION OF THE GROWTH OF THE FELLOWSHIPS IN VALUE.
K refers to the University of Kansas.
P refers to the University of Pittsburgh.

After the system had gotten well under way it became possible and advisable to establish Multiple Fellowships, as differentiated from Individual Fellowships. Multiple Fellowships employ the intensive services of several men under the immediate direction of a Senior Fellow, who is responsible for his juniors to the Director and his Associate. An Individual Fellowship relates to one Fellow only, who is responsible directly to the Associate Director and, through him, to the Director. Such Multiple Fellowships, for example, are K9, K13, P2, P4, P9.

While the time has not as yet arrived in any one case for the publication of results, it may be said that these results on the whole have been most gratifying; indeed, the system could not have survived, much less grown, except on the basis of progressive success. Quite apart from industrial results involving temporary secrecy, it has been found possible from time to time to publish papers of academic interest; such, for example, are Tillotson's papers on the "Surface Tension of Molten Glass," Weidlein's work on "Adrenalin," or Bushong's paper on "Iso-naphthenic Acids."

From the industrialists themselves we have received a generous, broad-minded trust and co-operation and the donation of many thousands of dollars' worth of apparatus in recognition of our progress.

The Fellows engaged in these researches, while they have been drawn from many different universities and other sources, have shown a complete understanding of the high trust which they hold and have developed a spirit of mutual helpfulness and an *esprit de corps* that is invariably a subject of favorable comment from visiting colleagues.

During the five years of actual development that this scheme has undergone, any inherent weakness must surely have appeared. It is most gratifying, then, at the conclusion of this paper, to state that none of us engaged in this work is aware of any such weakness. We look forward with confidence to the ultimate establishment of this system of Industrial Fellowships as a permanent relation between Industry and Learning.

November 23, 1912.

Use of Vanadium in Casting German Silver. C. P. KARR. (*Brass World,* viii, II, 392.)—Very perfect castings have been obtained by adding 4 ounces of cupro-nickel-vanadium to the molten bath about 5 minutes before the heat is ready to pour. The cupro-nickel-vanadium, either granulated or broken in small pieces, is wrapped in a piece of paper and dropped in the molten metal, and when it becomes cherry-red is pushed below the surface and held there by an inverted cup-disk, with a handle four feet long. It is held near the bottom of the pot until it is completely absorbed by the charge. Then stir the pot with a pumping motion and allow the charge to remain quiet about 5 minutes, during which the vanadium effects the purification. The vanadium is not deleterious to the crucible. When the metal reaches a clear, limpid condition, shown by its greater mobility, the heat is ready to pour. When the metal is in perfect condition, lambent flames of zinc oxide flare up at the sides.

Dyeing from Different Solvents. J. HÜBNER and H. B. AVERY. (*J. Soc. Dyers and Col.*, xxviii, 280.)—Dyeings made at the ordinary temperature with solutions of Benzopurpurin 10B in mixtures of water and alcohol showed that: (*a*) cotton absorbs less dyestuff from a mixed solvent than from either water or alcohol alone; (*b*) the point of minimum absorption is reached with a mixture of 45 per cent. of water and 55 per cent. of absolute alcohol by volume; (*c*) the cotton absorbs slightly less dyestuff from pure water than from absolute alcohol, and more from alcohol containing 5 per cent. of water than from absolute alcohol. If silk be used instead of cotton, the minimum absorption is reached with the same proportions of alcohol and water, viz., 55:45, and these proportions agree with the composition of the known hydrate of alcohol, C_2H_5OH, $3H_2O$, as shown by Varenne and Godefroy. Different results were obtained with mercerized cotton, the point of minimum absorption being reached with a mixture of 35 per cent. of water and 65 per cent. of alcohol. Methyl alcohol has practically no effect on the absorption of substantive dyestuffs by ordinary cotton, while mercerized cotton absorbs less dyestuff from methyl alcohol than from an aqueous solution. Dyeings from Benzopurpurin 10B in mixtures of water and glycerine showed that the absorption decreases as the proportion of glycerine increases.

Production of Nickel and Cobalt. CH. L. PARSONS. (*Bureau of Mines. "Notes on Mineral Wastes."*)—Nearly all the nickel used in the United States is imported from Canada. Large quantities are known to exist in Idaho, and an immense deposit of a low-grade, hydrous nickel-magnesium silicate lies at Webster, N. C. No economical method of utilizing this low-grade ore has been found. The larger part of the output from the Northwest is now used in the form of monel metal, an alloy of nickel and copper obtained direct from the ore, so the expense of first separating pure nickel has been avoided. Cobalt is almost solely found in imported Canadian silver ores from the famous Cobalt, Ontario, district.

The Aquarelle Process. M. WILCKE. (*Atelier Phot.*, xix, 87.)—This is similar to the gum process, is best suited to large prints, and is highly praised. Paper is coated with celluloid solution, dried, and then coated twice with a solution of 100 c.c. water, 40 Gm. sugar, and 4 Gm. half-hard gelatin, dissolved at not over 45° C. Then a coating of aquarelle color is applied with a brush, and the paper is sensitized in 6 per cent. ammonium bichromate thinned with an equal volume of alcohol. Printing is effected by the actinometer, and the image is developed by warm water sprayed through an atomizer.

NOTES ON THE FORMATION AND INHIBITION OF MILDEW IN PAINTS.[1]

BY

HENRY A. GARDNER,

Assistant Director, The Institute of Industrial Research, Washington, D. C.,
Member of the Institute.

THE formation of mildew upon the surface of green paints such as are used so widely upon the exterior trim and shutters of frame buildings has often been observed by the property owner. In damp localities, especially along the sea coast, the mildewing of painted exterior surfaces is not an uncommon sight, and the painter has searched in vain for materials which would prevent such conditions. A good opportunity was recently afforded the writer to study the subject of mildew, when, during the course of the examination of a red lead paint which had shown a peculiar thickening action, certain types of fungi were discovered. The paint had not hardened up as is usual with pure red lead paints which are kept in containers for a considerable period, but the pigment portion seemed to have no affinity for the oil in which it was ground, a peculiar gelatinous condition being observed. Around the edges of the paint a slight film had formed, and white spots were observed to be present upon the surface of this film. These white spots had the appearance of the type of mould that is often found upon damp basement walls. A portion of the skin was removed and preserved for microscopic examination.

There was obtained a sample of the original linseed oil in which the red lead had been ground, and it was thought advisable to examine this oil as well as the oil floating upon the top of the partially settled pigment, to find out whether both oils were pure. The analysis of the original oil gave the following results, which indicate that it was pure linseed oil:

Color: Light amber with a distinct green fluorescence.
Iodine number 185.2

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[1] Communicated by the author.

Acid number	3.4
Ash	.14%

The oil that was poured from the top of the settled red lead pigment had the following constants:

Iodine number	179.1
Acid number	8.8
Ash	2.78%

In the latter analysis the lower iodine value and higher acid number and ash presented differences which could easily be accounted for by the action of the red lead upon the oil. The analyses would therefore indicate that both samples of oil were pure. Curious to state, however, the oil that had been poured from the top of the red lead paint had an odor resembling fish oil, and the use of the latter oil might be held accountable for the condition of the paint. After standing in a bottle for forty-eight hours, the oil became very turbid and viscous, air bubbles having developed throughout the mass. Upon the surface of the oil there had formed a slight film which was covered with very small white spots. A portion of the oil was tested to determine whether there was any large amount of free glycerine present. A small amount was found, suggesting that hydrolysis had taken place. Such hydrolysis, however, might be accounted for by the action of the red lead upon the oil, wherein free fatty acid had been formed, accompanied by the splitting off of glycerine.

A more exhaustive test of the sample to determine whether fish oil was present was made according to the method outlined by Eisenschiml.[2] The original oil and the oil from the top of the can were separately dissolved in a mixture of chloroform and acetic acid and an excess of bromine added to each sample. The test-tubes containing these mixtures were placed in hot water for fifteen minutes. The original oil did not show any precipitated bromides, while the oil from the red lead paint showed a very large quantity. With raw oil, the precipitation of insoluble bromides would constitute a positive test that fish oil was present. It has recently been found, however, that this test is not of great value when applied to the examination of a boiled linseed oil. Inasmuch as the oil from the top of the red lead paint was shown by analysis to contain over 2 per cent. of lead ash, it might be considered of the same constitution as a boiled oil. Another test, however, which seemed to indicate the presence of fish oil, was made by rubbing a few drops of the oil briskly between the palms of the hands. A very rancid odor was immediately developed. This odor, however, might have been due to the presence of the free fatty acids in the oil, resulting from the hydrolyzing action of the red lead.

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[2] *Jour. Indus. and Eng. Chem.*, 1910, p. 43.

At this juncture in the research it was thought that considerable light might be thrown upon the work by a very careful examination to determine the unsaponifiable constituents of the oil. It is well known that in animal oils such as menhaden oil or other fish oils there is present an unsaponifiable constituent termed cholesterol, a crystalline alcoholic body which is entirely absent in vegetable oils such as linseed oil. The latter oil, however, and most other vegetable oils contain a similar unsaponifiable body termed sitosterol. These two bodies are easily differentiated by microscopic examination. Portions of the oils were separately treated with alcohol, the alcoholic extract being saponified and afterwards treated with ether.[3] The ether extract, containing the non-saponifiable bodies, was filtered and evaporated nearly to dryness, being subsequently filtered and then taken up with alcohol. Slow crystallization of the alcoholic solution resulted in the formation of tiny crystals which were examined under the microscope. Both the original oil and the oil used in the manufacture of the red lead paint deposited crystals which when observed under the microscope seemed to be in tufts of star-like groups, probably of a monoclinic system of crystallization (pure sitosterol). These crystals did not in any way resemble the crystals which are known as cholesterol, and the above tests presented pretty conclusive proof that the oil originally used was a pure vegetable oil. A similar test, however, was made with a sample of pure menhaden oil as a blank. After the usual course of treatment, there was obtained a considerable quantity of white crystals which when observed under the microscope appeared as flat, rhombic plates which are characteristic of the crystals of cholesterol. The melting point[4] of the crystals from the linseed oils used in grinding the red lead paint was not determined, the writer being unable

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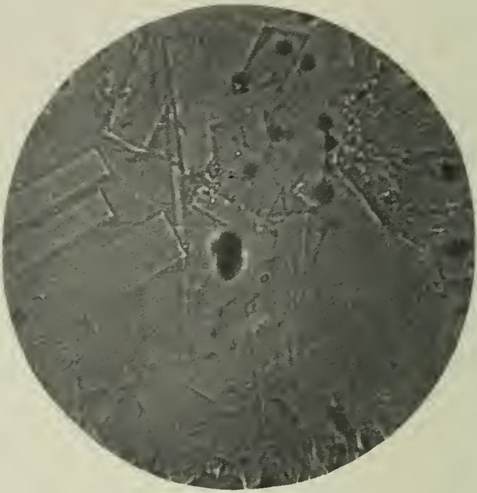
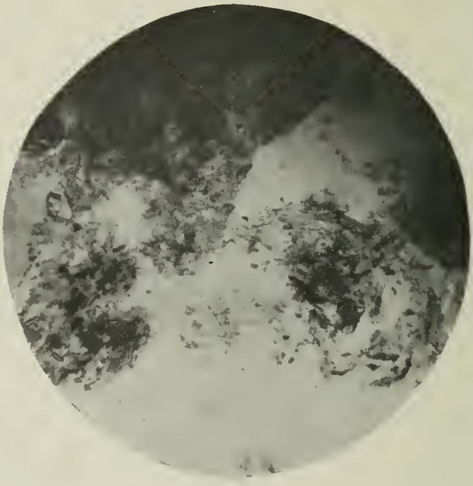
[3] *Jour. Soc. Chem. Indus.*, 17, 954, 1898; "Chemical Technology and Analysis of Oils," etc., Lewkowitsch, vol. i, p. 470; "Oil Analysis," Gill, p. 91.

FIG. 1.



Crystals of cholesterol extracted from menhaden oil. × 750.

FIG. 2.



Appearance of mould upon dried film of oil. × 750.

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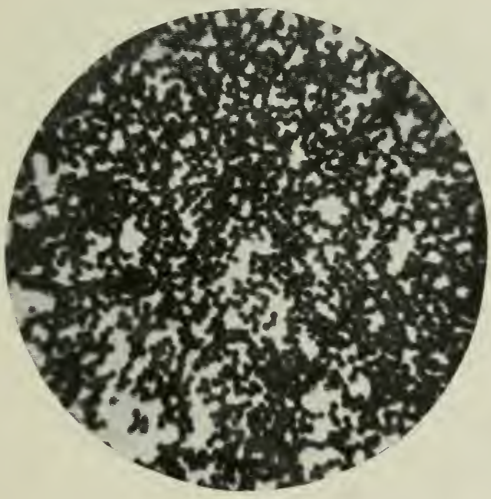
[4] *Jour. Soc. Chem. Indus.*, 1899, 557.

to find present any crystals which had the appearance of those found in the menhaden oil (see Fig. 1).

That the peculiar condition of the red lead paint, previously described, was due to the action of some type of micro-organisms seemed evident. Recourse was therefore had to the examination of what appeared to be mould upon the surface of the red lead paint previous to its chemical examination. A portion of the film upon which the mould had grown was carefully treated with ether to wash away any undried oil. After drying, the film was placed under the microscope. The appearance of the film is shown in Fig. 2. A test-tube culture in agar-agar was made of the mould upon the film. The surface of the agar-agar at the end of twenty-four hours was covered with a greenish mould, while there was shown to have developed downward through the jelly a peculiar white formation. Portions of both growths were examined under the microscope. The white portion was of unicellular structure, as shown in Fig. 3, while the green portion showed distinctly the mycelium with the attached cellular spores (see Fig. 4). These spores and mycelium have the distinct appearance of peniculum crustaceum. The writer is of the opinion spores which are responsible for the mildewing of

FIG. 3.

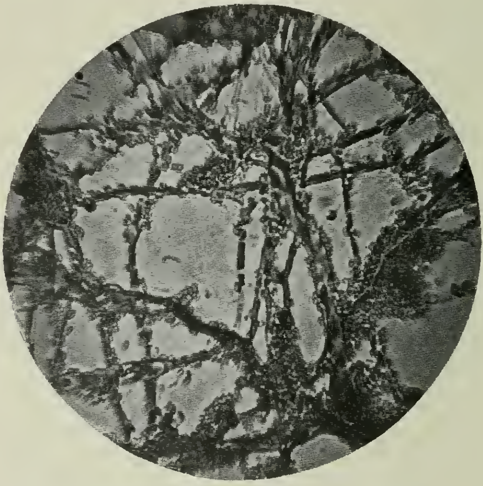


Culture of spores from linseed oil. × 750.

paint may exist in nearly all samples of raw linseed oil, as accidental impurities obtained from the exterior of the crushed seed.

The writer has previously found during the course of other experiments, conducted during the past few years, that the use of 5 per cent. of solvent naphtha of 160° benzol, added to the paint previous to application, prevents to a great extent the formation of mildew. On account of the xylol and toluol content of solvent naphtha, both of these constituents having high boiling points, they are retained in the drying film and they serve to inhibit the formation of the fungus. Another material which might serve the same purpose is refined pine oil, a water white product of very high boiling point, resulting from the distillation of turpentine. Both solvent naphtha and pine oil have excellent penetrative properties and when used in an exterior paint serve to carry the pigment into the fibres of the wood to produce a firm foundation coat.

FIG. 4.



Peniculum crustaceum growing upon linseed oil. Film × 750.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

THE ACTION OF THE SALTS IN ALKALI WATER AND SEA WATER UPON CEMENTS.[1]

By P. H. BATES, Ceramic Chemist; A. J. PHILLIPS, Assistant Chemist; RUDOLPH J. WIG, Associate Engineer Physicist.

THE paper describes a series of laboratory and field investigations made to determine the suitability and permanency of various cements in structures exposed to the chemical and mechanical action of the salts present in sea water and alkali water. The laboratory investigations consisted in subjecting various typical cements to salt solutions for a period of months, the solutions being renewed from time to time and their action noted by analyzing the solutions as removed and the residue at the end of the test. Small hollow cylinders of cement and cement mortar were made and exposed to the percolation of various salt solutions. Field investigations were made by exposing cements in the form of briquettes and concrete test pieces to sea water at a branch laboratory established at Atlantic City, N. J. The conclusions, as stated in the paper, are limited by the scope of investigation, and since the physical tests cover a period of exposure not exceeding two years, the conclusions are considered tentative.

1. Portland cement mortar or concrete if porous can be disintegrated by the mechanical force exerted by the crystallization of any salt in its pores if a sufficient quantity is permitted to accumulate, and the rapid formation of crystals is brought about by drying, and as larger crystals are formed by slow crystallization there will be obtained the same results on a larger scale but in a greater time if slow drying were had. Porous stone, brick, and other structural materials may be disintegrated in the same manner. Therefore, in alkali regions where a concentration of salts is possible a dense non-porous surface is essential.

2. While in the laboratory a hydraulic cement is rapidly decomposed if intimately exposed to the chemical action of

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[1] Abstract of Technologic Paper No. 12.

various sulphate and chloride solutions, field inspection indicates that in service these reactions are much retarded if not entirely suspended in most cases, due probably to the carbonization of the lime of the cement near the surface or the formation of an impervious skin or protective coating by saline deposits.

3. Properly-made Portland cement concrete when totally immersed is apparently not subject to decomposition by the chemical action of sea water.

4. While the tests indicate that Portland cement concrete exposed between tides resisted chemical decomposition as satisfactorily as the totally immersed concrete, it is felt that actual service conditions were not reproduced, and therefore further investigation is desirable.

5. It is not yet possible to state whether the resistance of cements to chemical disintegration by sea water is due to the superficial formation of an impervious skin or coating which is subsequently assisted by the deposition of shells and moss, forming a protective coating, or by the chemical reaction of the sea salts with the cement, forming a more stable compound without disintegration of the concrete, or by a combination of both of these phenomena.

6. Marine construction, in so far as the concrete placed below the surface of the water is concerned, would appear to be a problem of method rather than materials, as the concrete sets and permanently hardens as satisfactorily in sea water as in fresh water or in the atmosphere, if it can be placed in the forms without undue exposure to the sea water while being deposited.

7. Natural, slag, and other special cements tested in concrete mixtures showed normal increase in strength with age both in sea water and in fresh water.

8. In the form of neat briquettes most of the cements of high iron content, and several of the cements of high or normal alumina content, did not show any marked difference in tensile strength whether exposed to fresh or sea water for all periods up to one year. Other cements of various composition showed signs of disintegration after a few weeks.

9. All cements resisted disintegration in sea water better in mortar mixtures than in the form of neat briquettes.

10. The physical qualities of the cement, which depend

essentially upon the method of manufacture, would seem to determine its resistance to decomposition when brought into intimate contact with the sulphate and chloride solutions.

11. Contrary to the opinion of many, there is no apparent relation between the chemical composition of a cement and the rapidity with which it reacts with sea water when brought into intimate contact.

12. Tricalcium-sulpho-aluminate could not be formed, and therefore disintegration could not result from this cause.

13. In the presence of sea water or similar sulphate chloride solutions:

(*a*) The most soluble element of the cement is the lime. If the lime of the cement is carbonated it is practically insoluble.

(*b*) The quantity of alumina, iron, or silica present in the cement does not affect its solubility.

(*c*) The magnesia present in the cement is practically inert.

(*d*) The quantity of SO_3 present in the cement up to 1.75 does not affect its solubility, but a variation in the quantity present may affect its stability by affecting its rate of hardening.

14. The change which takes place in sea water when brought into intimate contact with the cement is as follows:

(*a*) The magnesia is precipitated from the sea water in direct proportion to the solubility of the lime of the cement.

(*b*) The sulphates are the most active constituents of the sea water, and are taken up by the cement. Their action is accelerated in the presence of chlorides. No definite sulphate compound was established.

(*c*) The quantity of chlorine and sodium taken up by the cement is so small that no statement can be made as to the existence of any definite chloride or sodium compound formed with the cement.

15. The SO_3 added to a cement in the plaster to regulate the time of set is chemically fixed so that it will not go into solution when the cement is brought into intimate contact with distilled water.

16. Metal reinforcement is not subject to corrosion if imbedded to a depth of 2 inches or more from the surface of well-made concrete.

THE DIFFUSE REFLECTING POWER OF VARIOUS SUBSTANCES.

BY

W. W. COBLENTZ, Ph.D.,

Associate Physicist, U. S. Bureau of Standards.

Corrected Table.*

TABLE I.

Reflecting Power of Lampblack.

Wave-length. λ max.	.54μ	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%	%
Silver	93.2	89.9	93.4	94.6	98.0	98.0	98.5
Aluminum		68.5			92.3		
Correction factor	1.102	1.143	1.100	1.086	1.049	1.049	1.043
Lampblack Paint		2.94			3.24		
		3.02			2.29		
		3.58			3.60	Alcohol + shellac.	
		3.72			4.86		
		3.10	3.38	3.36	3.34	3.75	4.4
Paraffin candle (hot)			0.97				
(Cold soot)		1.07 1.43					
Rosin			1.26		1.31		
					.85	1.07	2.8
Sperm candle			.91		.67	1.44	3.9
			1.02		.93	1.27	4.1
			1.25		1.03		
			1.07		.77	1.28	
			1.01		1.36	1.23	
					1.28	.87	
Camphor			1.34		1.38	1.46	
			1.30		.95	1.65	5.7
			1.36		1.15		
(Paint)			2.80		3.24		
Acetylene			.59				
			.82		.92	1.12	3.0
			.64		.71	1.24	
			.54		.81		
			.42		.71		
(Cold deposit)			.86				
(No air)			1.33				

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* See article November, 1912, vol. clxxiv, p. 564.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, December 18, 1912.)

Hall of The Franklin Institute,
Philadelphia, December 18, 1912.

President Walton Clark *in the Chair.*

Additions to membership since last report, 55.

The following nominations were made for officers and managers to be voted for at the annual election held January 15, 1913:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Henry Howson.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Robert S. Perry, E. H. Sanborn.

The Chairman then introduced Dr. Isham Randolph, Consulting Engineer, of Chicago, who presented the paper of the evening, entitled "The Engineer in the Building of the Republic."

The development and progress of transportation by means of canals and railroads was reviewed, and the achievements of the engineer in the construction of bridges, dams, reclamation and irrigation plants were enumerated. Interesting information was presented relating to the growth of the railroads of the United States, their trackage, siding, etc., and the increase in the horsepower of locomotives since their first introduction. Reference was made to many notable engineering projects, including the Panama Canal, the Roosevelt Dam, the Chicago Drainage Canal, the hydro-electric plants at Niagara Falls and elsewhere, and the problem of supplying large cities with water.

On motion of Mr. Dodge, duly seconded, the thanks of the meeting were extended to Dr. Randolph.

Adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 4, 1912.)

Hall of The Franklin Institute,
Philadelphia, December 4, 1912.

Dr. George A. Hoadley *in the Chair.*

The following report was presented for final action:

No. 2499.—Santo Vacuum Cleaner. Advisory. Adopted.

The following reports were presented for first reading:

No. 2512.—Rosanoff's Methods of Determining Partial Vapor Pressures. Advisory. Adopted.
No. 2518.—Hopkins' Thermal Indicator.
No. 2521.—Hoover Suction Sweeper. Advisory. Adopted.

The following was accepted for examination:

No. 2522.—Gaede's Molecular Air Pump.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held on Thursday evening, December 5, 1912, in the Hall of the Institute, at 8 o'clock. This was a joint meeting of the section and the Philadelphia Section of the American Institute of Electrical Engineers.

The meeting was called to order by the Chairman, Mr. George R. Henderson. The reading of the minutes of the previous meeting was dispensed with, and, after a few introductory remarks, the Chairman introduced Mr. H. T. Herr, Vice-President and General Manager of the Westinghouse Machine Company, who read a paper on "Recent Advances in the Steam Turbine Art." The paper was illustrated by numerous lantern slides, and the speaker brought out very clearly the characteristics of the different types of steam turbines and their advantages and disadvantages.

The paper was followed by a few remarks by Mr. Henderson and a short discussion by Professor Lanza and Mr. J. A. P. Crisfield, after which a vote of thanks was tendered Mr. Herr and the meeting adjourned.

FRANK B. STEM,
Secretary.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute, on Thursday, December 12, 1912, at 8 P.M.

Dr. Harry F. Keller occupied the Chair.

With a few introductory remarks, the Chairman introduced Dr. Wilder D. Bancroft, Professor of Physical Chemistry at Cornell University, Ithaca, N. Y.

Dr. Bancroft gave an interesting and entertaining lecture on "Chemiluminescence."

After explaining the meaning of the term, he went on to show how, in the light of present knowledge, it might well be applied to all forms of luminescence, such as photo-luminescence, cathodo-, anodo-, electro-, pyro-, etc.

He gave demonstrations to show that, in the chemical production of light, the intensity of light produced was a function of the velocity of reaction.

He spoke of the light of the firefly as being undoubtedly of chemical nature and said that this light could be duplicated if a chemical reaction could be discovered which took place with sufficient velocity but at the same low temperature.

The thanks of the meeting were extended to Dr. Bancroft.

Adjourned.

WM. E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. WALTER R. ADDICKS, No. 4 Irving Place, New York, N. Y.
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MR. JAMES H. WYATT, Cutler Electric and Manufacturing Company, corner Nineteenth and Hamilton Streets, Philadelphia, Pa.

NON-RESIDENT.

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J. T. AINSLIE WALKER, F.R.S.M., F.C.S., Whitehall Building, New York, N. Y.

MR. J. T. WALLIS, Superintendent Motive Power, Pennsylvania Railroad Company, Altoona, Pa.

MR. GEO. B. WELLINGTON, 17 First Street, Troy, N. Y.

Changes of Address.

MR. NICHOLAS W. AKIMOFF, 1013 Harrison Building, Philadelphia, Pa.

MR. W. H. ALBERTSON, 334 North Preston Street, Philadelphia, Pa.

Mr. Franklin Baker, Jr., corner Wayne Avenue and Hortter Street, Germantown, Philadelphia, Pa.
Mr. J. B. Baker, Thirty-second and Powelton Avenue, Philadelphia, Pa.
Mr. W. P. Bement, 743 Real Estate Trust Building, Philadelphia, Pa.
Prof. James C. Biddle, Jr., Abbey of Gethsemani, Trappist P. O., Ky.
Mr. George Breed, 1516 Commonwealth Trust Building, Philadelphia, Pa.
F. T. Chambers, Esq., 1530 Pine Street, Philadelphia, Pa.
Mr. Edward B. Clark, 1018 Munsey Building, Washington, D. C.
Mr. E. W. Desher, 134 South Fifty-fourth Street, Philadelphia, Pa.
Mr. Evans R. Dick, 30 Broad Street, New York, N. Y.
Mr. Paul Didier, Principal Assistant Engineer, Baltimore & Ohio Railroad Company, N. S. Pittsburgh, Pa.
Mr. Wm. A. Doble, Nineteenth and Harrison Streets, San Francisco, Cal.
Mr. Thomas J. Dolan, 2107 Walnut Street, Philadelphia, Pa.
Mr. Wm. J. Doyle, 1519 Sansom Street, Philadelphia, Pa.
Mary C. DuBois, 1733 Pine Street, Philadelphia, Pa.
Mr. J. H. Eastwick, 2260 North Fifty-third Street, Philadelphia, Pa.
Mr. Wm. P. Evans, 500 North Fifteenth Street, Philadelphia, Pa.
H. B. Gill, Esq., 518 Real Estate Trust Building, Philadelphia, Pa.
Mr. Charles M. Hall, 131 Buffalo Avenue, Niagara Falls, N. Y.
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Mr. C. Kirchhoff, 587 Riverside Drive, New York, N. Y.
Mr. Simon I. Kohn, 720 Market Street, Philadelphia, Pa.
Mr. G. C. Leidy, Whitehall Hotel, 107th Street, Cleveland, Ohio.
Mr. E. F. Mason, University Club, Altoona, Pa.
Mr. James Hartley Merrick, Roxborough, Philadelphia, Pa.
Mr. Wm. H. Merrick, Schoolhouse Lane, Germantown, Philadelphia, Pa.
Mr. Henry F. Mitchell, Thirty-sixth and Reed Streets, Philadelphia, Pa.
Mr. Louis M. Pawlett, 231 Fairfield Avenue, Bridgeport, Conn.
Mr. Kurt W. Peuckert, Sharon Hill, Delaware County, Pa.
Mr. John T. Ramsden, 1911 North Seventeenth Street, Philadelphia, Pa.
Mr. Jesse W. Reno, 684 St. Nicholas Avenue, New York, N. Y.
Mr. Edward Rowland, W. & H. Rowland, Inc., Frankford, Philadelphia, Pa.
Mr. J. B. Rumbough, P. O. Box 912, Asheville, N. C.
Mr. Samuel Shoemaker, 1831 Land Title Building, Philadelphia, Pa.
Mr. Arthur H. Thomas, West Washington Square, Philadelphia, Pa.
Mrs. F. Von A. Cabeen, New Britain, Bucks County, Pa.
Mr. Alois Von Isakovics, Synfleur Scientific Laboratories, Monticello, N. Y.
Mr. George Von Utassy, 381 Fourth Avenue, New York, N. Y.
Mr. Francis R. Welsh, 109 South Fourth Street, Philadelphia, Pa.
Mr. John R. Wiggins, 1215 Filbert Street, Philadelphia, Pa.
Mr. H. W. Wilson, 1060 Drexel Building, Philadelphia, Pa.
J. L. Wilson, Esq., Room 608, 608 Chestnut Street, Philadelphia, Pa.
Mr. John Jacob Wolf, 927 North Fifth Street, Philadelphia, Pa.
Mr. Asa W. Whitney, 500 Georgia Avenue, Bristol, Tenn.
Dr. Francis Wyatt, 20 Fifth Avenue, New York, N. Y.
Lieut. A. B. Wyckoff, 131 East H Street, Ontario, Cal.

NECROLOGY.

William Laws Boswell was born in Philadelphia on June 22, 1828. He was educated in the public and private schools, and finally attended the University of Pennsylvania, where he was graduated in 1848. Later, he became an instructor in Dickinson College, after which he was ordained to the ministry, and was a member of the Philadelphia Methodist Episcopal Conference three years. He finally became an insurance broker, in which business he continued to 1904.

Mr. Boswell was a trustee of Dickinson College. He was elected to membership in the Institute in 1872, and became a life member ten years later.

Mr. George Burnham, 3401 Powelton Avenue, Philadelphia, Pa.
Mr. F. F. Milne, 1714 Spruce Street, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

American Institute of Chemical Engineers, Transactions, vol. iv, 1912.
BOOTH, W. H., and J. B. C. KERSHAW.—Smoke Prevention. 1906.
BOYLE, R., and E. H. AMAGAT.—The Laws of Gases. 1899.
BUCHANAN, J. F.—Practical Alloying. 1910.
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MERRIMAN, M.—Treatise on Hydraulics. 1912.
Mineral Industry. 1911.
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TUTTON, A. E. H.—Crystals. 1911.
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American Blower Company, Catalogue of Products. Detroit, no date. (From the Company.)
American Railway Master Mechanics' Association, Proceedings, vol. xlv, 1912. Chicago, 1912. (From the Association.)
American Rolling Mill Company, Methods for the Analysis of Iron and Steel used in their Laboratories. Middletown, Ohio, 1912. (From the Company.)
Amsterdam Royal Academy of Sciences, Year Book for 1911 and Proceedings of the Section of Science. Amsterdam, 1911–12. (From the Academy.)
Baylor University, Annual Report of the President and Trustees, October, 1912. Waco, Tex., no date. (From the University.)
Chicago, Department of Smoke Inspection, Report for February, 1911, and February, 1912. Chicago, 1911–12. (From the Department.)
Cooper (C. and G.) Company, Catalogue of Cooper Gas Engines. Mount Vernon, Ohio, 1912. (From the Company.)
Great Britain, Board of Trade, Report on Changes in Rates of Wages and Hours of Labour in the United Kingdom, 1911. London, 1911. (From the Department of Labour.)
Herculanum et Pompéi, Recueil général des peintures, bronzes, mosaïques, etc., découverts jusqu'a ce jour, et reproduits d'après le antichita di Ercolano, il museo Borbonico et tous les ouvrages analogues par H. Roux Ainé. Paris, 1861–1863. Eight volumes. (From Mr. Richard Waln Meirs.)
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Institution of Mining and Metallurgy, Transactions 21st Session, 1911–12, vol. xxi. London, 1912. (From the Institution.)
Iowa Board of Railroad Commissioners, Annual Report for 1911. Des Moines, 1912. (From the Commission.)
Isthmian Canal Commission, Report on the Panama Canal Traffic and Tolls, by Emory R. Johnson. Washington, D. C., 1912. (From Mr. E. R. Johnson.)

Locomobile Company of America, The Car of 1912. Bridgeport, Conn., 1912. (From Mr. John T. Morris.)

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Murphy Iron Works, Catalogue of the Murphy Automatic Furnace. Detroit, no date. (From the Works.)

National Machinery Company, Catalogue of Products Manufactured by the National Machinery Company. Tiffin, Ohio, no date. (From the Company.)

Neptune Motor Company, Catalogue of Trident Water Meters. New York, 1912. (From the Company.)

New York Public Service Commission, Annual Report, 1910, Pt. 4; 1911, Pt. 1. Albany, no date. (From the Commission.)

New York State Education Department, Annual Report for 1912. Albany, 1912. (From the State Library.)

North Carolina Geological and Economic Survey, Economic Paper No. 28, Culverts and Small Bridges for Country Roads in North Carolina. Raleigh, 1912. (From the Survey.)

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Palmer, Truman G., Sugar at a Glance. Charts and Data. Washington, D. C., 1912. (From the Hon. H. C. Lodge.)

Permanent International Association of Navigation Congress, 12th Congress, Philadelphia, Pa., 1912. 1st Section, Inland Navigation, 2d Section, Ocean Navigation. Philadelphia, no date. (From Mr. James Donald.)

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Power Specialty Company, The Foster Superheater. Philadelphia, 1911. (From the Company.)

Richardson, George W., The Slide Rule Simplified. Chicago, 1911. (From the author.)

Smith College Bulletin, Official Circular, 1912–1913. Northampton, Mass., 1912. (From the College.)

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Triumph Electric Company, Bulletin for August, 1910, to August, 1912. Cincinnati, no date. (From the Company.)

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White (S. S.) Dental Manufacturing Company, Catalogues of Products. Philadelphia, no date. (From the Company.)

Whiting Foundry Equipment Company, General Catalogue of Cranes, Cupolas, and Air Hoists. Harvey, Ill., 1912. (From the Company.)

Yale University, Astronomical Observatory, Transactions vol. ii, parts 3 and 4. New Haven, 1911. (From the Observatory.)

PUBLICATIONS RECEIVED.

La Théorie des Ions et l'Électrolyse par Auguste Hollard. Deuxième édition, entièrement refondue. 220 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1912. Price, 5 francs.

Smoley's Tables. Parallel tables of logarithms and squares. Diagram for solving right triangles. Angles and logarithmic functions corresponding to given levels. Common logarithms of numbers. Tables of logarithms and natural trigonometric functions and other tables for engineers, architects, and students, by Constantine Smoley, C.E. Seventh edition, revised and enlarged. 329 + 174 pages, 12mo. New York, McGraw-Hill Book Company, 1912. Price, in leather, $3.50.

Engineering of Shops and Factories, by Henry Grattan Tyrrell, C.E. 399 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1912. Price, in cloth, $4.

North Carolina Geological Survey: Economic Paper No. 27, Highway Work in North Carolina, containing a statistical report of road work during 1911, by Joseph Hyde Pratt, State Geologist, and Miss H. M. Berry, Secretary. 145 pages, illustrations, plates, maps, 8vo. Raleigh, State Printers, 1912.

National Association of Cotton Manufacturers. Transactions No. 92, Annual Meeting, April 24-25, 1912. 452 pages, illustrations, plates, 8vo. Boston, Association, 1912.

Annuaire pour l'an 1913 publié par le Bureau des Longitudes, Avec des notices scientifiques. 883 pages, illustrations, 16mo. Paris, Gauthier-Villars, no date. Price, in paper, 1 franc 50c.

U. S. Department of Agriculture: Forest Service. Bulletin 113, Methods and Apparatus for the Prevention and Control of Forest Fires, as Exemplified on the Arkansas National Forest, by Daniel W. Adams, Forest Examiner. 27 pages, illustrations, 8vo. Bulletin 117, Forest Fires: Their Causes, Extent, and Effects, with a summary of recorded destruction and loss, by Fred. G. Plummer, geographer. 39 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines: Bulletin 46, An Investigation of Explosion-proof Motors, by H. H. Clark. 44 pages, illustrations, plates, 8vo. Technical Paper 25, Methods for the Determination of Water in Petroleum and its Products, by Irving C. Allen and Walter A. Jacobs. 13 pages, illustrations, 8vo. Technical Paper 27, Monthly Statement of Coal-mine Accidents in the United States, January to August, 1912, and Statistics for

1910 and 1911, compiled by Frederick W. Horton. 24 pages, 8vo. Washington, Government Printing Office, 1912.

A Study of Trolley Light Freight Service and Philadelphia Markets in their Bearing on the Cost of Farm Produce, by Clyde Lyndon King, Ph.D., Wharton School of Finance and Commerce, University of Pennsylvania, made under direction of Rudolph Blankenburg, Mayor, Philadelphia. 58 pages, map, 8vo. Philadelphia, Department of Public Works, October, 1912.

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Philadelphia Bureau of Water: Water Supply Educational Series Bulletin No. 2, A Study in Industrial Water Charges. 48 pages, 8vo. Philadelphia, Bureau of Water, November, 1912.

Idioma Auxiliar Internacional, Historia de la delegacion para su adopcion por Claro C. Dassen, Ingeniero Civil, Doctor en ciencias fisico-mathematicas. 51 pages, 16mo. Buenos Aires, Jose Cuneo, 1911.

BOOK NOTICE.

ANALYSIS OF METALLURGICAL AND ENGINEERING METHODS, by Henry Wysor, B.S., Assistant Professor of Analytical Chemistry and Metallurgy in Lafayette College, Pa. The Chemical Publishing Company, Easton, Pa., 1912, $2.00.

This is a student's text-book, or manual, intended for beginners in quantitative analysis, as well as for advanced workers, containing an introductory chapter in which many principles are generalized.

The table of contents shows that it covers methods of sampling ores, analyzing limestone, Portland cement, coal and coke, iron ores, copper ores and matte, lead ores and furnace products, zinc ores; analyses of iron, alloy steels, ferro-manganese and iron rich in manganese, brass and bronze, soft bearing metal; analysis of water; analysis of producer gas; calorimetry of coal, coke, oil and gases; examination of lubricating oil; examination of the micro-structure of iron and steel; heat treatment of metals; tables of atomic weights and bibliography, etc.

This is an extensive field to be covered in a book having 73 pages of printed matter and 9 pages of cuts.

It is needless to say that there is no overelaboration under these limitations. On the contrary, there are some omissions. For example: Under the heading of "Analysis of Iron" the method of "determination of silicon in pig iron and high silicon iron" is condensed into the space of five and a half lines.

The method given is the very well known rapid one, but this is *not* applicable to pig iron *high* in silicon, for the reason that such iron will not dissolve in the solvents named, a mixture of sulphuric and nitric acids. An entirely different method of treatment is necessary where silicon is present in considerable proportion. The nickel crucible generally used in the analysis of ferro-silicon is not mentioned at all in the book, nor is any method given for analyzing ferro-silicon, an omission that is more remarkable from the fact that a page is devoted to the analysis of ferro-manganese and iron rich in manganese.

Another strange omission noted is the total absence of an index, while the table of contents gives no reference to pages and the book is not arranged in chapters.

Alternate pages are left blank for insertion of notes by the student, and the book will doubtless be found useful in connection with a teacher's instructions.

The book is claimed to be "a systematic arrangement of laboratory methods," and this claim appears to be substantiated upon examination.

Methods for determination of vanadium, titanium, chromium, and tungsten in iron are given in a few very brief paragraphs, and as these elements in alloy steels have assumed great importance in recent years a more extended description of the best analytical methods, with a statement of the precautions necessary to avoid errors, would seem to be advisable in order to enhance the permanent value of the book and to extend its usefulness beyond the immediate range of the author's classes.

A. E. OUTERBRIDGE, JR.

CURRENT TOPICS

After-Luminosity of Electric Discharge in Hydrogen. R. J. Strutt. (*Roy. Soc. Proc., Ser. A,* lxxxvi, 529.)—Hertz described a phenomenon of after-luminosity which he observed in hydrogen on passing a series of jar discharges through a small discharge tube with an open end, arranged inside a bell-jar. It was observed that at each discharge a steam of luminous gas was ejected from the end of the small discharge tube into the bell-jar. He sometimes observed a jet of blue luminosity, which was best developed at a pressure of 100 mm., and considered he had good evidence that this luminosity showed the hydrogen spectrum, but he found an unaccountable capriciousness of the effect, which sometimes did not appear at all. He failed to trace the cause of this uncertainty. Goldstein made similar experiments; he says that the spectrum consists of at least 10 bands, from the green to the ultra-violet, totally unrelated to the hydrogen spectrum. But he believed the glow was due to pure hydrogen. With the same apparatus the spectrum of the glow is now obtained, and is found identical with that of active nitrogen passed over heated sulphur. The blue glow in hydrogen, then, is connected with the presence of sulphur as an impurity in the gas. On cooling in liquid air an annex of the vessel in which the glow is observed, so as to condense hydrogen sulphide (or any sulphur compound), the glow disappears in one or two minutes. On removing the liquid air, and allowing the glass to warm up, it is restored to its full brilliancy.

Diesel Engines. Anon. (*Amer. Mach.,* xxxvii, 4, 149.)—The increase in size of the Diesel engine is noteworthy. Engines of some hundreds of horsepower have become common in Europe. in Swiss electric stations Diesel engine units of 2000 horsepower are now in use, and it is said that the development of the large-sized Diesel engine has been so successful that before long it will not be deemed extraordinary to develop 1000 horsepower in one cylinder. One company of world-wide reputation is considering over 2000 horsepower in the single cylinder of Diesel engines. Engines of this type with four cylinders developing 1000 horsepower each can be made as light as the corresponding triple-expansion steam engine. The weight of such engines compares favorably with that of the corresponding turbines and boilers. A 1000-horsepower installation of this type weighed only 187 pounds per horsepower, as compared with 180 pounds for a steam turbine and boiler installation.

The International Photometric Commission, commonly known as the "Zurich Commission," was created by the International Congress of Gas Industries which convened in Paris in 1900. This Commission, composed of representatives from the various national technical gas societies, with the co-operation of certain of the national laboratories, has been concerned with general questions of photometry in addition to its more specific functions in connection with the photometry of the incandescent mantle.

Inasmuch as there has developed a widespread appreciation of the need of an international, thoroughly representative commission to deal with general questions of photometry, and possibly also of illumination, it has been proposed that the International Photometric Commission be reorganized to fulfil these requirements in a way acceptable to all photometric interests This movement is being well received both in Europe and America.

President Vautier of the International Photometric Commission has requested the Sub-Commission on Photometric Units and Standards to formulate a plan of reorganization. This Sub-Commission was originally appointed at the 1911 session of the International Photometric Commission to consider the recommendations of the Illuminating Engineering Society (U. S.) regarding photometric nomenclature and standards. The Sub-Commission at present is composed of the following members: Dr. Brodhun, Dr. Kusminsky, M. F. Laporte, Mr. C. C. Paterson, Secretary, M. Th. Vautier, Ex-Officio, and a representative of the United States soon to be appointed. The personnel of the Sub-Commission, composed of representatives of the various national laboratories, is peculiarly qualified to undertake the duty of formulating plans of reorganization. It is hoped that as the outcome of the efforts of the Sub-Commission, with the endorsement of the various national technical gas societies to which the International Photometric Commission in the past has been responsible, an essentially new Commission will be formed which will be equally representative of and responsible to all national technical gas, electric and illuminating engineering societies, and other bodies interested in photometry and illumination.

Velocity of Secondary Rays Liberated by Canal Rays. H. BAERWALD. (*Deutsch. Phys. Gesell. Verh.*, xiv, 675.)—The velocity of secondary rays liberated from solid substances by canal rays has been found by C. Füchtbauer to be 30 volts, while Lenard has shown that secondary rays due to cathode rays have only 10.8 volts velocity. In the present experiments the velocity of the secondary rays set free from solid bodies by the canal rays is found to be of the same order of magnitude as those liberated from solids by cathode rays. This indicates similarity in the mechanism of procedure in the two cases. Further experiments are being undertaken.

Heat of Evaporation of Liquid Air. G. WITT. (*Ark. för Mat. Astron. och Fysik,* vii, 32.)—The liquid air was contained in a Dewar vessel, and a known amount of heat was added by passing an electric current through a resistance immersed in the liquid. The amount of liquid evaporated was determined by measuring the volume of air expelled; and blank experiments were made to determine the rate of evaporation when no heat is applied. Since the latent heat of vaporization varies with the composition of the liquid air, this composition must be determined. This was effected by measuring the temperature of the liquid during the experiments by means of a thermo-junction and calculating the composition from the boiling point by means of Baly's measurements. The latent heat, L, in Gm. calories is given by the equation $L = 49.59 + 0.0143\ p$, where p is the percentage of oxygen in the liquid air. The latent heats of nitrogen and oxygen are therefore 49.59 and 51.92 Gm. calories respectively. By the application of Clapeyron's equation to the experimental results obtained by other observers for the boiling point, difference in specific volumes of the liquid and gas, and alteration of the boiling point with the pressure of pure nitrogen and oxygen, the latent heats are calculated to be 48.9 and 51.4 Gm. calories respectively, which values agree well with the author's experimental results.

Cassegrain Telescope Mounting. E. SCHAER. (*Archives des Sciences,* xxxiii, 201.)—After some remarks on the adjustment of telescopes in general, there is given a description of the construction of a large Cassegrain reflector for the Observatory of Geneva during 1909–1910. The focal length is 295 cm.; the diameter of the large mirror is 100 cm.; the equivalent focal length is 1760 cm. The equatorial movement is controlled by an oil clepsydra driven by a 60 kg. weight. At the ocular end fittings are provided for photographic plates of 13 x 18 cm. Several photographs are reproduced showing the satisfactory performance of the instrument.

Gapless, Granular, Three-color Screens for Color Photography. J. BAMBER. (*Eng. Pat.* 15, 755, July 7, 1911.)—A suitable support, such as glass or celluloid, is coated with a layer of varnish consisting of 1 part gum sandarach, 1 part castor oil, 2 parts lavender oil, and 4 parts alcohol; while this is still adhesive the color grains are applied to it in a thin layer. These are prepared by coloring with suitable dyes the grains obtained from a mixture of 4 parts gum sandarach, 1¼ parts castor oil, and 12 parts of alcohol. By using these mixtures the color grains absorb the oil from the varnish and become permanently plastic. The screen is now subjected to the action of a solvent vapor, *e.g.*, alcohol, wood-naphtha, or acetone, and allowed to dry. The grains momentarily dissolve and the solvent evaporates so rapidly that the grains form a continuous layer, but the colors do not intermingle.

Conversion of Nitrogen into its Compounds. J. A. A. AUZIES. (*Rev. Gen. Chim. fur. appli.*, xv, 233.)—After consideration of the known methods of oxidizing atmospheric nitrogen, it is deduced from theoretical reasoning that the yield is improved 25 per cent. by the use of a gas current of 50 per cent. nitrogen and 50 per cent. oxygen. Tables illustrate the relation between temperature and yield. The oxidation of nitrogen has been effected by the use of catalysts, apparently by the formation of unstable peroxides which yield active oxygen. These catalysts are obtained by the calcination of the hydroxides of cobalt, magnesium, chromium, nickel, platinum, palladium, barium, lead, cerium, and thorium. The best results are obtained with thorium oxide or mixtures containing it. The 50 per cent. mixture of gases is obtained by enriching air with oxygen produced as a by-product in the manufacture of nitrogen by fractional distillation of liquid air. The gas current is dried and then passed over plates on which the catalyst is spread in thin layers, which are heated to a suitable temperature. The further oxidation of nitric oxide to peroxide is effected in chambers at 150° C., and is accelerated by the influence of ultra-violet radiation. The yield is improved when the pressure in the chamber is raised to about 5 atmospheres. The products of the reaction are passed into a receiver cooled in liquid air, which retains the nitrogen peroxide and allows the nitrogen and oxygen to pass back again through the apparatus. For the preparation of ammonia from nitrogen by catalysis with nickel, iron, cobalt, boron, titanium, aluminum, etc., it is essential that the nitrogen and hydrogen should be absolutely free from oxygen, and the mixture is first passed through a solution of chromous sulphate. The catalyst is generally prepared by soaking raw cotton in a solution of a salt of the metal, then in solution of ammonia and igniting. Only those metals, the oxides of which are not reducible by hydrogen, must be used in the powdered condition. The gas current is passed over the catalyst in tubes which are heated red hot in metal baths, and the product of the reaction is quickly cooled below 500° C. As examples of the proportions for mixing the catalysts, these are suggested: 22 parts of boron, or 55 parts of aluminum to 168 parts of reduced nickel. The formation of ammonia is due to the preliminary production of an unstable boron nitride and the activation of the hydrogen by the reduced nickel.

Retardation of the β-Rays in Their Passage through Matter. O. V. BAEYER. (*Physik. Zeit.*, xiii, 485.)—The penetrating β-rays of thorium A, after passing through very thin foils of aluminum, tin, copper, or platinum, show a somewhat greater deviation in the magnetic field than the incident rays; therefore it is concluded that the β-rays are slowed down somewhat in their passage through matter. The retardation in copper tin, and platinum is less than in equivalent thickness of aluminum, but the absorption is greater.

Durobax: A New Glass for Gauge Glasses. H. THIENE. (*Zeitschr. Instrumentenk. Beib.*, xvi, 165.)—The desirable qualities of a boiler gauge-glass are: strength to resist pressure, insensitiveness to boiler fluctuations, and immunity to chemical action of steam or feed-water. Practically all gauge-glasses will stand 200 to 300 atmospheres in the cold state. Heated up to boiler temperature and sprayed at regular periods, the strengths are considerably decreased and vary greatly; thus French will stand 6 atmospheres; English, 7; Verbund-Robax, 15; Durax, 27; and Durobax, 31 atmospheres. The makers of Durobax seem to have improved on their resistance to attack by steam and feed-water, as their gauge-glasses remain clear for a long time.

Electric Furnace for Non-ferrous Metals. (*Mech. Eng.*, xxx, 125.)—This type of resistance furnace, or a combination of arc and resistance furnace, is the invention of R. S. Wile and has been developed by the Pittsburgh Electric Furnace Company. Four carbon electrodes are used, two through the bottom and two through the top. The specialty is that when preparing to make a heat the furnace is partially filled with broken glass, and the carbon electrodes are arranged so that an arc is formed which melts the glass. As the glass becomes molten it acts as a conductor, and when it is very fluid the electrodes are moved farther apart and the metal is charged into the furnace; this sinks to the bottom, and the fluid glass protects it from oxidation. The glass can be used for several months. In melting brass scrap the loss can be kept as low as 1⅓ per cent.

Permanent Fireproofing of Cotton Goods. W. H. PERKIN. (*Eighth International Cong. Appl. Chem.*)—A description is given of the series of experiments which led to the commercial production of permanently fireproofed flannelette. The first process worked on a commercial scale consisted in treating the material successively with sodium stannate and with a mixture of sodium tungstate, zinc acetate, and acetic acid. The treated material, however, tended to become damp, the fireproofing was not sufficiently permanent, and the cost of the process was too high. The process finally arrived at was this: the flannelette is impregnated with a solution of sodium stannate of about 45° Twaddell, squeezed, dried on heated copper drums, passed through a solution of ammonium sulphate of about 15° Tw. to precipitate the tin oxide, again squeezed and dried, washed to remove the sodium sulphate, dried, and finished as usual. The tin oxide is probably present in actual combination with the fibre, for the fireproofing is not destroyed by repeated washing with hot water and soap. The treated material can be dyed the most delicate shades, exerts no deleterious action on the skin, and is stated to be stronger and more durable than the untreated material. With tin at £210 per ton, the cost of the process is not more than 1d. per yard. The process is applicable to muslin, lace curtains, etc.

The Ageing and Preservation of Wood. M. de Keyhel. (*Rev. Gén. Chim.*, xv, 85.)—*Ageing.*—Old wood contains about 10 per cent. of water held mechanically in the pores of the wood, and this amount is independent of the relative humidity of the atmosphere. Green wood changes its size and shape on account of the water being absorbed by hygroscopic substances in the sap. Artificial ageing is produced by extracting these hygroscopic substances, by this method, viz.: the wood is immersed for 24 hours in a solution of 600 Kg. of 26° Be. tetra-isol, 250 Kg. ammonia, and 100,000 litres water. This solution is driven out by immersing the wood in Me_2CO and recovering the latter by heating in a retort. Wood can be given a very high electrical resistance by immersing it in a bath of linseed oil after the Me_2CO treatment and heating it to 70° C. *Preservation.*—A preservative must possess these characteristics: it must be in a sufficiently fluid solution to penetrate the whole of the wood, which is impossible with creosote; it must become insoluble after the solvent has evaporated, and must form a stable combination with the sap; it must not change the qualities of the tissues of the wood as regards elasticity, suppleness, and resistance to mechanical action, and must make the cellulose able to resist insects; it must be cheap and not dangerous to handle. Formulas are given for preservatives that have produced excellent results.

Specifications for the Oil for Mixing with Concrete. (*Bull. XLVI. Office of Public Roads, U. S. A.*)—These specifications are given for residual oils intended for waterproofing concrete according to L. W. Page's process. (1) The oil shall have a specific gravity of 0.930 to 0.940 at 25° C. (2) At least 99.9 per cent. shall be soluble in carbon bisulphide at the ordinary temperature. (3) It shall contain 1.5 to 2.5 per cent. of bitumen insoluble in paraffin naphtha of 86° Be. (4) It shall yield 2.5 to 4 per cent. of residual coke. (5) When 240 c.c. of the material are heated to 50° C. in an Engler viscosimeter and maintained at this temperature for at least 6 minutes, the first 100 c.c. which flow out shall show a viscosity of 40 to 45. (6) When 20 grammes of the material are heated to 163° C. for 5 hours in a cylindrical tin vessel, 2½ inches diameter by 1 inch high, the loss in weight shall not exceed 2 per cent.

Active Deposits from the Air in the Bolivian Andes. W. Knoche. (*Physik. Zeit.*, xiii, 440.)—The active deposits obtained on charged insulated wires at an elevation of 5200 metres proved remarkably radioactive. The surface rocks were relatively inactive. These active deposits consisted of radium, thorium, and probably actinium products, but the radium always predominated. Slight activities were also obtained on neutral and positively charged wires.

Fireproofing and Insulation of Wood. M. DE KEYHEL. (*Rev. Chim. Ind.*, xxiii, 152.)—This is a discussion of principles, methods, and materials, from which the conclusion is reached that impregnation under pressure is the most efficient method. As a general principle each species of wood requires a different pressure for the necessary penetration, but the pressure remains constant for the same species, regardless of the dimensions of the piece to be impregnated. The penetration of the wood by a crystalloidal liquid is a function of the time. When displacement and penetration take place in a longitudinal sense, irrespective of pressure, the rapidity or duration of the injection will always be in direct relation to the length; for a given length and constant pressure, for the same species, the rapidity may, in certain cases, vary with the initial capillary speed, depending on the concentration of the injected solution. The species generally used are oak, mahogany, teak, ash, beech, gum, walnut, poplar, fir, pitch pine, pine, and birch. The double phosphate of zinc and ammonia obtained by dissolving zinc hydroxide in ammonium hydroxide, and adding phosphoric acid, is superior to any other salt for impregnation, and is the only one that can be applied without inconvenience. The method of making it on a large scale is given.

Soldering Lead Pipes with Lead. ANON. (*Amer. Mach.*, xxxvii, 4, 151.)—The soldering of lead pipes with lead or "lead-burning" was known and practised in the Middle Ages. Vincent de Beauvais, who died in 1264, wrote: "If tin is exposed to a moist atmosphere, it will corrode; but human ingenuity has of late invented useful improvements by which it is possible to unite leaden subterranean water pipes with the aid of *molten lead* instead of soldering with tin. Pipes soldered with the latter metal never lasted long, but if lead is used it will last for all time."

The Preservation of Wood with "Bellit." NOWOTNY. (*Oesterr. Chem. Ztg.*, xv, 100.)—Sodium fluoride is mixed with nitro-phenols to increase its preservative effect. One of these compounds, known as "Bellit," consists of 90 parts of 90 to 95 per cent. sodium fluoride with 10 parts of dinitrophenolaniline. This latter is an active antiseptic and has no action on the iron vessels used for impregnating. The selective phenomena observed with mixtures of zinc fluoride and hydrochloric acid are also observed in the "Bellit" process.

Delta Rays. N. CAMPBELL. (*Phil. Mag.*, xxiii, 46.)—The speed of the δ-rays is independent of the speed of the α-rays which excite them, as well as of the material from which they emanate. The magnetic methods hitherto used to measure the speed of the δ-rays are considered somewhat untrustworthy.

The Absorption and Scattering of the Alpha Rays. C. G. DARWIN. (*Phil. Mag.*, xxiii, 901.)—Accepting the atomic structure proposed by Rutherford, a hypothesis is presented which assumes that the α particles in passing through matter draw electrons out of the atoms they traverse, acting on them according to the ordinary law of the inverse square, and losing their own velocity by thus imparting motion to a cluster of electrons. A velocity curve equation has been deduced connecting the velocity of the α particles with the distance they have traversed from their origin, which agrees closely with the curve found by experiment. It contains two unknown constants, n, the number of electrons in each atom, and σ the radius of the atom. Assuming the latter in the case of air, the former can be deduced from the range of the particles. Widely different values of σ give very similar values for n. From a computation of the retarding powers of air and other substances, σ and n can be deduced for these. The number of the electrons in the atom appears to be intermediate between the atomic weight and its half. The atomic radii decrease as the atomic weight increases. In the cases of hydrogen and helium the equation does not seem to apply. A similar formula is developed for scattering, and in all cases gives results which agree closely with the experimental observations.

Large Castings for the New White Star Liner. ANON. (*Eng.*, xciv, 2438, 391.)—The Darlington Forge Company have gained a world-wide reputation in producing castings of record dimensions. Difficulties have been experienced in conveying these castings from the forge to their destination, as these castings often extend over a double set of rails. Consequently they travel by rail on Sundays when the lines are clear. These conditions were arranged for them when the stern frame of the latest White Star liner was conveyed to West Hartlepool, where the large North-Eastern Railway cranes placed the castings on board for shipment to Belfast. This stern frame weighed nearly 80 tons, and was in two sections. It was a larger casting than the firm supplied for the *Titanic*.

Radioactivity of the Carlsbad Springs. W. KOLHÖRSTER. (*Ber. Physik. Ges.*, 1912, 356.)—Many investigators have shown that the Carlsbad spring waters contain dissolved radium salts. This radium can be separated nearly quantitatively by adding a few drops of barium chloride solution to the boiling water, which has been acidified by sulphuric acid. This simple method removes all but one per cent. of the radium in the water from the thermal spring, the radium content of which was found to be approximately 5.5×10^{11} grammes per litre. The iron hydroxide separated when the water is aërated does not remove the radium salts. A trace of thorium emanation was detected in the water.

A New Strong Brass Alloy Containing Silicon. ANON. (*Brass World,* viii, *II,* 390.)—This alloy is patented by Alfred Schmid in U. S. Patent 1,040,027, October 1, 1912. The best proportions are:

Copper	58 pounds
Zinc	40 pounds
Tin	1 pound
30 per cent. silicon copper	1 pound

which makes the true proportions:

Copper	58.70%
Zinc	40.00%
Tin	1.00%
Silicon	0.30%

Tensile strength, 68,000 to 78,000 pounds per square inch.

Elastic limit, 28,000 to 42,000 pounds per square inch.

Elongation, 25 per cent. to 35 per cent.

There are no shrink holes, and the alloy does not segregate. It is malleable when red hot, and may be rolled or forged.

The Pennsylvania Chestnut Tree Blight Commission has just issued for the information of the public Bulletin No. 1, giving the means of identifying the chestnut blight disease and suggesting remedies for its control and eradication.

The document points out the great danger of extermination that menaces Pennsylvania's vast chestnut resources, and urges a prompt and vigorous co-operation generally in the efforts to stamp out this new but terribly destructive pest of our native chestnut trees.

The disease has already entailed losses to timber owners in Pennsylvania amounting to fully ten millions of dollars, having been especially virulent in southeastern Pennsylvania, where thousands of trees were killed by the blight. West of the Allegheny Mountains, by a concentrated effort of the Commission and timber owners, the blight will practically be wiped out by the close of the year, thus giving the assurance that a large portion of Pennsylvania's many millions of dollars' worth of chestnut may be saved, and the disease checked before it can spread into the valuable timber of adjacent States.

The bulletin describes many phases of the blight, and the warfare that is being waged to control the outbreak. It defines very clearly that, contrary to the erroneous opinion advanced by one or two writers, the blight is of a parasitic form, and the trees are not killed by any insects, as has been stated. The fungus is spread, however, by the wind, animals, birds, insects, etc., and when trees are infected it soon girdles the twigs, branches, and trunks, thus causing their death.

At this season of the year, when chestnut trees are found with branches bearing dry leaves and immature burrs, cankers, orange-colored pustules, etc., it is an indication that the tree is seriously diseased.

The bulletin also refers to the economic and profitable utilization of trees killed by the blight. The Commission acquired much valuable information upon the subject, and can therefore prove of genuine service to those seeking markets for commercial products of the chestnut.

Chestnut nursery stock can only be sold and shipped after it has been carefully inspected and properly tagged. A tree that does not appear to be entirely free from the disease is condemned and burned.

Copies of the bulletin are available and will be sent without charge upon request to the Commission, Morris Building, Philadelphia.

Chlorides in Feed-water. E. E. BASCH. (*Techn. Rundschau,* xvii, 561.)—The main source of corrosion in steam boilers is magnesium chloride. The boiler plate becomes overheated under the boiler scale, and the hydrochloric acid is set free and causes corrosion. Sodium chloride is considered harmless until it oversteps the saturating point, and so precipitation occurs. A mixture of lime and soda is successfully used to make magnesium chloride harmless. Caustic soda can be used also, but is more expensive. The only remedy for an excess of sodium chloride is its removal by distillation, which is too expensive.

The New Hydra Photographic Plate. O. MENTE. (*Atelier Phot.,* xix, 82.)—The gradation of the image is not between the deepest shadow and the highest light, as in ordinary plates, but between the deepest shadow and some one high light, as all higher lights have this same density and no solarization appears. Exposures not exceeding forty times normal may be developed with pyro-soda, but a special developer is recommended for exposures beyond this limit. The absence of halation is partly due to the thickness of the film and partly to a red backing, the color of which disappears in the fixing bath.

Explosion of Radium Bromide. B. JOST. (*Chem. Zeit.,* xxxvi, 138.)—Occasional explosions of specimens of radium bromide are attributed to the gradual absorption of moisture, which weakens the forces of cohesion in the crystal to the point where the pressure of the accumulated emanation (helium) suddenly ruptures the crystal.

The Original Source of Metalliferous Ores. G. W. MILLER. (*Mining Eng. World,* xxxvi, 515.)—The presence of igneous rocks, which is generally favorable to ore deposits at some place near by, may affect the development of ore deposits in various ways: (1) They may furnish metal for the ores; (2) or water and gaseous solutions which facilitate the transportation of the metals. (3) Their heat may render the solution vastly more active in segregating the ores from the parent igneous rocks. (4) Their introduction may promote fracturing and thus open channels for circulation. (5) Open channels may be formed by the cooling and consequent contraction. (6) They may furnish avenues in the way of long and deep-seated, impervious trunk channels of circulation. (7) They are often easily soluble and hence afford large avenues for the reception of ores through the processes of metasomatic replacement. The origin of ores is to be sought in the igneous rocks which they generally accompany. Through volcanism the molten rocks are brought to the upper zones of the lithosphere, where they are subjected to the leaching processes of the circulating underground waters, which extract their metals and transport and redeposit the soluble metals as ores in the variously-formed receptacles along the water passages. In some localities evidence points to the formation of ore deposits by magmatic segregation, deposits formed by fumaroles, by subterranean mineralized gases, etc., but the sum of these is considered insignificant in comparison with those deposits formed through the processes of circulating underground waters.

Plasticity of Clay. J. STEWART. (*Eighth Int. Cong. Appl. Chem. Sect. vii,* xv, 265.)—The suggestion is made that the plasticity of clay is due to the presence of an organic aluminum compound. This assumption is claimed to explain satisfactorily all the established facts concerning the plasticity of clay. For example, it explains why only impure clays are plastic; why ignition destroys and levigation fails to restore plasticity; the industrial practice of weathering clay before use, and why the plasticity is reduced by bases, since the aluminum organic compound is soluble in alkali.

Nickel-plating Electrogalvanized Articles. ANON. (*Brass World,* viii, II, 385.)—W. Feuerhake, of Westphalia, has patented a process for making iron or steel articles rust-proof and at the same time giving them a good finish. The iron or steel goods are first electrogalvanized, and then lightly copper-plated from a copper cyanide solution. Then nickel plate is deposited on the copper, which produces an excellent, rust-proof finish. The object of copper-plating is that, while nickel can be plated direct on zinc, it is unsatisfactory as a commercial proposition, and it is always advisable to copper the zinc first.

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RECENT DEVELOPMENTS IN STEAM TURBINES.*

BY
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INTRODUCTORY.

CLOSE association with the more recent developments in steam turbine design and construction has fixed firmly in the writer's mind the necessity for a good understanding of the fundamental scientific principles involved, together with extended intelligent experimental investigation, in order that successful and economical operation, now demanded, may obtain, and that the future may keep pace with that advancement in the art which has been accomplished in the last decade.

Development in any art or science is advanced in proportion to the proper understanding of its principles and an intelligent co-operation and application on the part of those who use such art or science experimentally and commercially.

The more widely the principles of turbine design, construction, and operation are disseminated and understood, with the proof of such principles experimentally, the more rational will be the use of this prime mover commercially and the more rapidly and highly developed will its structure become.

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* Presented at the meeting of the Mechanical and Engineering Section held Thursday, December 5, 1912.

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The purpose, therefore, of this paper is to give such fundamental principles and information on recent developments in the turbine art as are consistent with the space permissible, with the hope that those interested in the subject and associated with the development of power from steam may become better acquainted with the points which are important for reliable operation and economy and better informed on the main facts relating to the development of the steam turbine and its more recent application and performance in practice.

EARLY HISTORY.

In a manuscript by Hero of Alexandria the earliest notices of heat engines of any kind are recorded. This manuscript was probably written 150 B.C., and contains a description of a steam reaction turbine, an illustration of which is shown in Fig. 1.

From the time of Hero down to the seventeenth century, practically no record of progress in steam engines is extant.

In 1629 Branca, an Italian architect, designed a steam turbine (Fig. 2) driven by a jet of steam directed by a nozzle on vanes attached to a wheel.

Branca's wheel had all the essential parts now common to the modern impulse turbine, except it was not housed in a casing.

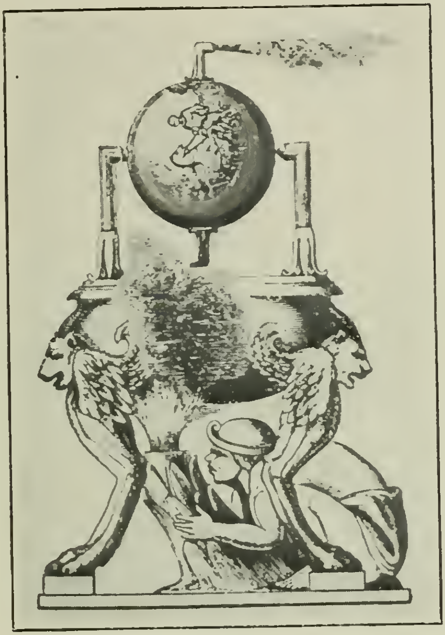
It is probable that if Hero and Branca had understood the laws governing steam as we know them to-day, and had had the benefit of our present knowledge of materials and tools, they would have made successful machines. The lack of such knowledge, however, delayed for centuries the development of this prime mover.

Until the end of the nineteenth century, although in the interval many steam turbines and rotary engines were patented, the reciprocating steam engine under Watts's initiative held commercially an unrestricted field and passed through many remarkable developments.

RECENT HISTORY.

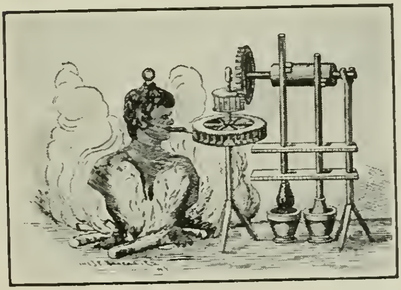
The period of experimental development of the turbine art may be said to have occurred since 1880, only after the evolution of the modern mathematical and physical sciences, when the action of steam could be understood and the machine properly designed and constructed in safe and economical forms with the aid of modern tools and materials.

FIG. 1.



Hero's turbine.

FIG. 2.



Branca's turbine.

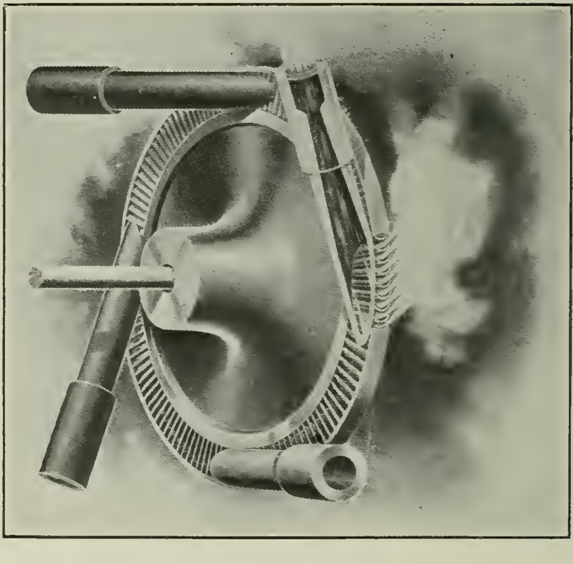
Practically nothing of value was accomplished in the turbine art until about 1882, when De Laval constructed his first steam turbine, similar in principle to Hero's reaction engine.

The economy of this machine was unsatisfactory, and for other reasons the inventor turned his attention to the development of Branca's turbine with remarkable results.

After much experimenting, De Laval developed an impulse turbine, which is still one of the standard makes (Fig. 3).

Almost contemporaneously with De Laval, C. A. Parsons, in England, began the development of his reaction turbine, and the practicability of the design he then proposed showed that much time and thought had been given to constructive details.

FIG. 3.



Bucket wheel and nozzles of De Laval steam turbine.

Methods for reducing vibration, preventing leakage of steam, and providing for efficient lubrication contributed very largely to its success.

In his early experiments Parsons also tried a simple reaction turbine, following almost exactly the published designs of Hero. During the period from 1882 to 1903 distinct types of turbines were introduced, called, after the names of the inventors, De

Laval, Parsons, Curtis, and Rateau, all consisting, with the exception of the De Laval turbine, of a multiplicity of fundamental parts designed on the principle of simple impulse or reaction elements.

ELEMENTARY PRINCIPLES.

For a proper understanding of the sequence of events following the recent history of the turbine from 1903 to date it is necessary to comprehend the fundamental principles on which the operation of turbine engines depends. Like the steam and gas engine, the turbine is a machine for obtaining mechanical work from heat energy. A full conception, therefore, of its underlying principles requires a knowledge of pure and applied thermodynamics, as well as familiarity with mechanics and experience in machine design and construction.

The turbine converts the heat energy of a gas into useful mechanical work by transforming such heat energy into velocity and then extracting the energy in such velocity by means of the rotation of a spindle, caused by the impulse and reaction of jets of steam on suitably-designed blades or vanes.

The conversion of the heat energy of a gas involves principles in thermodynamics which for convenience have been put into Appendix I, and are a compilation of notes made by the author while tutoring at Yale.

All commercial types of turbines—steam, water, or gas—are divided into two general classes, viz., (1) impulse and (2) reaction. Strictly speaking, all steam turbines use both impulse and reaction in their operation, as the blades of the rotor are moved by the impulse and reaction of impinging jets of steam issuing from nozzles or passages essentially equivalent to nozzles.

Fig. 4 illustrates the impulse of a jet of water issuing from a vessel and impinging upon a flat board hinged opposite. As the result of the force of the jet, the board will obviously move to the right. As the jet issues from the vessel it exerts a reaction on the tank, tending to move it to the left.

Fig. 5 is intended to illustrate the significance of impulse and reaction as they are used in turbine practice. In this case water from a vessel impinges against the curved surface, as shown in the illustration, and before it leaves this surface is turned back through an angle of 180 degrees. The board is therefore acted on by two forces simultaneously, both tending to move it to the right. The jet striking the board creates an impulse, and, when leaving the board, a reaction, both of which are equal and in the same direction, frictional losses neglected. If the jets in Figs. 4 and 5 have the same velocity and density, with friction neglected, the pressure on the block in Fig. 5 will be twice that on the block in Fig. 4.

FIG. 4.

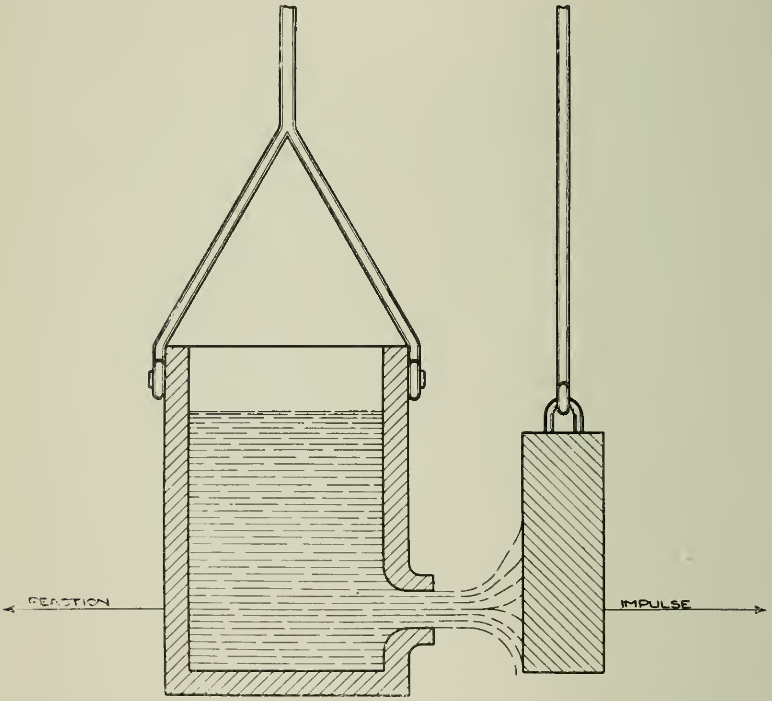
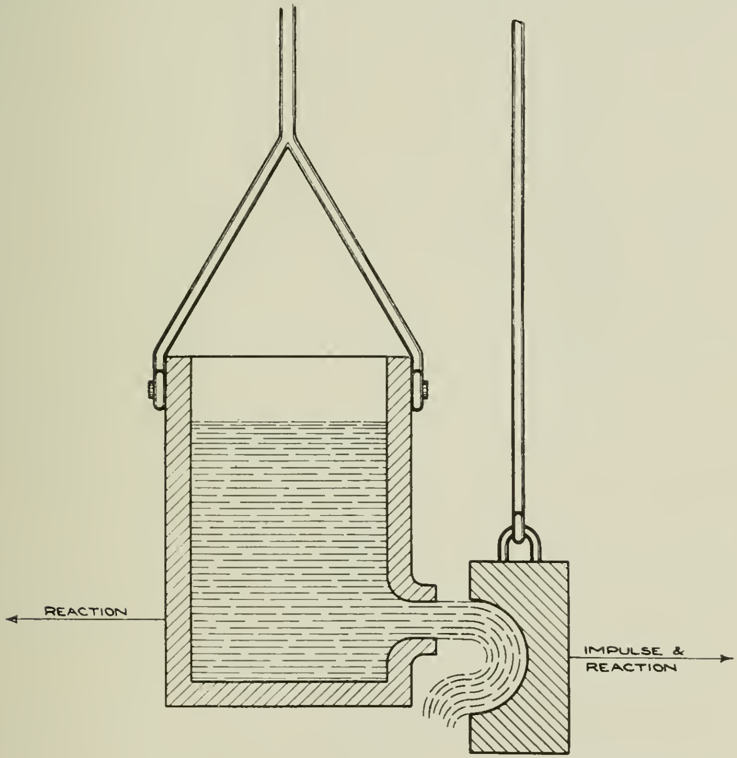


Fig. 6 illustrates a nozzle and blade wheel in which the blades have a single curvature, *i.e.*, the steam in its passage through the blades is not turned back on itself. If this wheel were held stationary the steam would leave the blades in a direction nearly parallel to the shaft. The only force, therefore, effective for moving the blades is the impulse of the jet.

Fig. 7 indicates a blade wheel and nozzle in which steam from the nozzle enters the blades in a direction parallel to the axis, the jet then being turned backward through an angle less than 90 degrees. On leaving the blades the jet exerts a reaction on the wheel, which, if held stationary, would be felt as a force tending to turn it.

Fig. 8 shows blades with nearly 180 degrees curvature, which turn the steam back on itself on leaving the blades. The wheel would therefore be moved first by the impulse of the jet, and then by its reaction.

FIG. 5.



It has been shown in Appendix I that when steam expands through an orifice or passage it acquires a velocity proportional to the drop in pressure which it undergoes.

In the so-called impulse turbines this expansion takes place in a fixed nozzle, and the energy of the steam, due to its velocity, is absorbed in the revolving blades of a wheel without drop in pressure through the blades themselves.

In the reaction turbine the expansion of steam takes place in the blades themselves, and the velocity of the steam caused by such expansion is converted into useful work by its reaction in leaving the blades.

As a matter of fact, all steam turbines make use of both the impulse and reaction of a steam jet acting on the blades. It is the way in which the blades are constructed and applied that distinguishes the different types of turbines, and it may be said that all impulse machines depend on the absorption of the steam velocity, due to a drop in pressure, through suitable nozzles, there being little or no pressure drop through the blades themselves; while the reaction turbine, on the other hand, utilizes the velocity of steam, caused by a drop in pressure through the blades themselves, to rotate the turbine spindle.

FIG. 6.

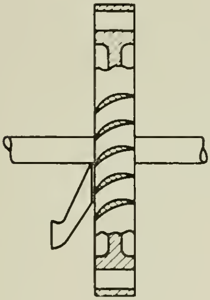


FIG. 7.

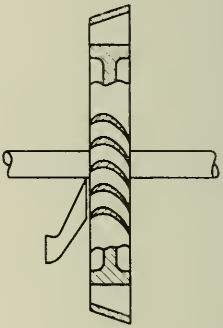
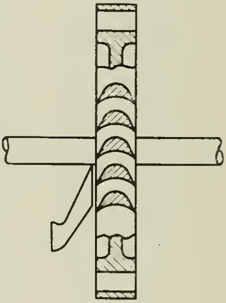


FIG. 8.



Compounding stages of the simple impulse or reaction element constituted the development of the turbine to 1903.

Prior to this date there were four distinctive systems in use in various countries:

First, the impulse, action, or velocity system represented by the De Laval turbine and its various modifications.

Second, the multi-stage impulse system represented by the Rateau and Zoelly turbines.

Third, the subdivided multi-stage impulse system represented by the Curtis and Riedler-Stumpf turbines.

Fourth, the reaction or pressure system represented by the various forms of Parsons turbine.

The distinctive characteristics of the impulse and reaction turbine elements lie almost entirely in the fact that in the impulse element expansion of steam is carried out within a system of nozzles, while in the reaction element expansion occurs within the blades themselves, both stationary and moving, but in successive small steps.

The function of a steam nozzle is the production of the desired velocity, while that of its corresponding blade or blades is to absorb this velocity for the production of useful work. Here the pressure drop is almost entirely confined within the nozzle and is non-appreciable through the blades.

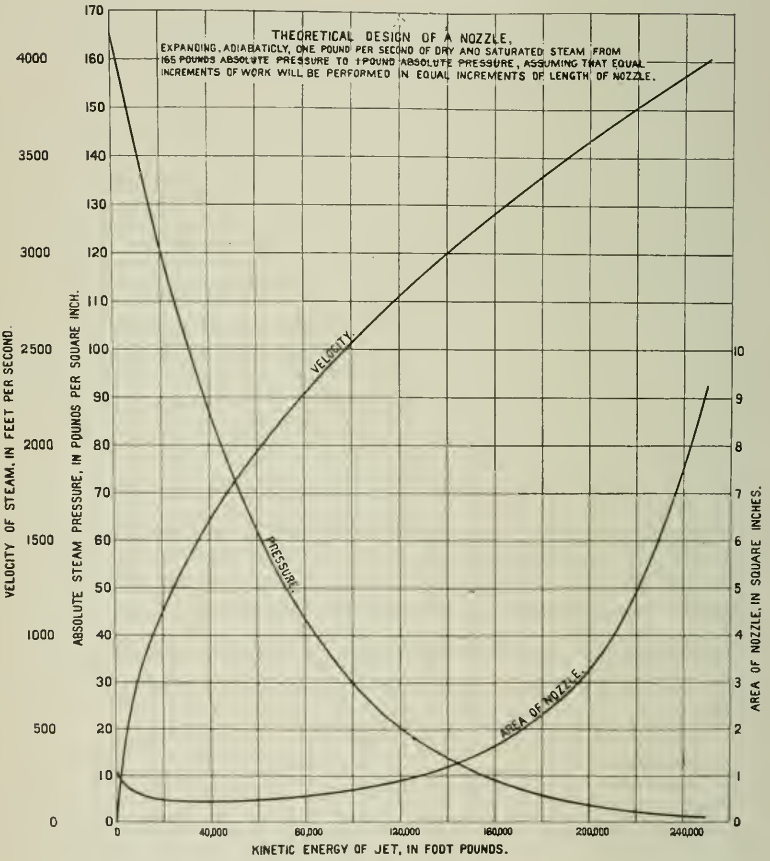
On the other hand, in the reaction turbine there are no nozzles, the blades corresponding thereto, as noted above. In the expansion within the blades a reactive thrust is produced in the opposite direction from the issuing steam jet, which thrust forms the major part of the turning moment of the reaction turbine, and hence its classification as such. The remainder, which is but a small factor, is produced by impulse action of steam from the various stationary rows of blades.

A definite relation must exist between steam velocity and blade velocity for the production of maximum efficiency.

Theoretically, in the pure impulse system the moving blades must recede at one-half the velocity of the impinging jet for maximum efficiency. In the pure reaction turbine the moving blades must recede at the same velocity as that of the steam jet in order to absorb all the velocity therein. This would appear to constitute a point in favor of the impulse system. In the reaction system the apparent objection is overcome by the simple expedient of employing more expansion stages. All this presupposes a tangential direction of the steam jet parallel to the plane of rotation.

With side jets, such as are of necessity used in practice, it is impossible to obtain a complete reversal of the jet, and hence a part of the jet velocity is unavailable.

FIG. 9.



It is a general impression that the 1 to 1 velocity ratio must hold in reaction turbines. This is not the case, for, as has been said, the reaction system not only contains impulse principles but also uses side jets, so that the relative blade and jet speed, for the best efficiency, must fall somewhere between .5 and 1.0.

The multi-stage, (Rateau) impulse system was developed to overcome the chief difficulty of the simple impulse element, viz., the efficient utilization of the enormous steam speeds resulting from a single expansion over wide ranges of pressure.

Fig. 9 plots the velocity resulting from the expansion of steam from a pressure of 165 pounds to 1 pound absolute in a nozzle designed for uniform work. Thus a steam speed of over 4000 feet per second is obtained for the full expansion to 28 inches vacuum. This would theoretically require a speed of 7640 revolutions per minute for an impulse wheel 5 feet in diameter—a mechanical impracticability—but by subdividing the expansion into a number of stages the velocities per stage can be reduced to practical limits. This involves the familiar multicellular construction used in the Rateau turbine.

In the subdivided multi-stage (Curtis) impulse system a modification of the foregoing may be secured, viz., blade speeds two or three times lower than the jet speed may be used. This is accomplished by two or more impulse wheels per stage, each absorbing its share of the total velocity delivered by the nozzles.

With a given jet velocity a two-stage impulse wheel would rotate at one-half the speed of a single impulse wheel, a three-stage wheel at one-third, etc.

It has been shown in Appendix I that the energy of a jet of steam of velocity V is $\frac{V^2}{2g}$, and the velocity of the steam with a suitably designed nozzle is dependent on the drop in pressure through such nozzle.

It is customary to diagram by vectors the action of a steam jet through the various stages of a turbine, making certain allowances, established by practical experimentation, for losses due to the physical properties of steam and the construction of the turbine elements.

In Figs. 10 to 16 inclusive such velocity diagrams are illustrated for the four types of turbines, viz., De Laval, Rateau, Curtis, and Parsons, together with diagrams of the blading of each type. The curves in the diagrams illustrate the action of the steam as regards pressure and velocity through the different stages.

Such velocity diagrams comprehend the absolute and relative velocities of the steam jets and blades, the absolute velocities

Fig. 10.

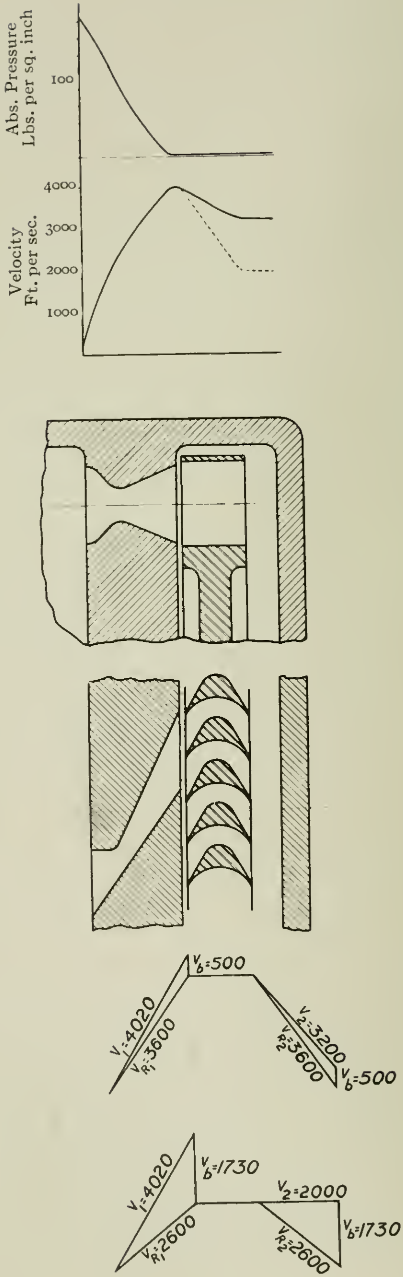
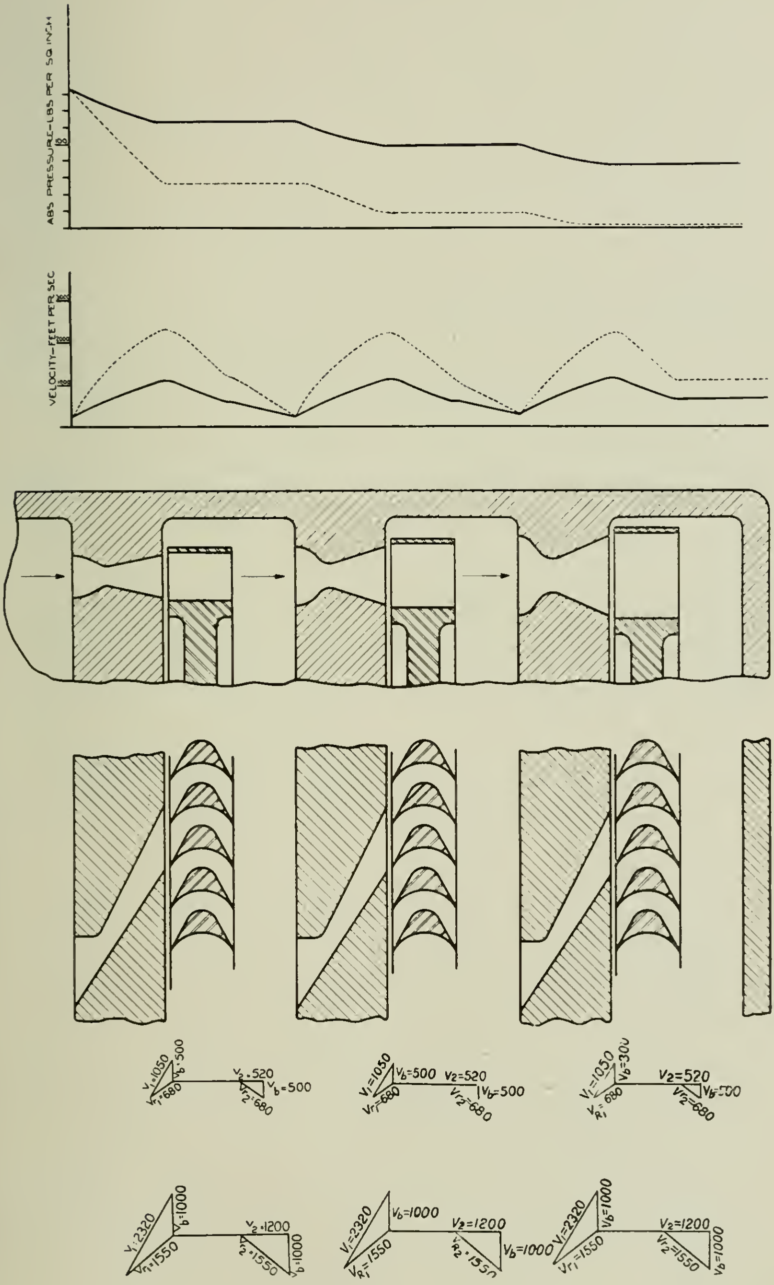

Abs. Pressure
Lbs. per sq. inch
100
Velocity
Ft. per sec.
4000
3000
2000
1000
V_b=500
V_1=4020
V_R1=3600
V_2=3200
V_R2=3600
V_b=500
V_1=4020
V_b=1730
V_R1=2600
V_2=2000
V_R2=2600
V_b=1730

FIG. 11.


ABS PRESSURE-LBS PER SQ IN.
10
VELOCITY-FEET PER SEC
3000
2000
1000
$V_1=1050$
$V_b=500$
$V_{r_1}=680$
$V_2=520$
$V_b=500$
$V_{r_2}=680$
$V_1=1050$
$V_b=500$
$V_{r_1}=680$
$V_2=520$
$V_b=500$
$V_{r_2}=680$
$V_1=1050$
$V_b=500$
$V_{R_1}=680$
$V_2=520$
$V_b=500$
$V_2=680$
$V_1=2320$
$V_b=1000$
$V_{r_1}=1550$
$V_2=1200$
$V_{r_2}=1550$
$V_b=1000$
$V_1=2320$
$V_b=1000$
$V_{R_1}=1550$
$V_2=1200$
$V_{R_2}=1550$
$V_b=1000$
$V_1=2320$
$V_b=1000$
$V_{r_1}=1550$
$V_2=1200$
$V_{r_2}=1550$
$V_b=1000$

being recorded with reference to the earth, and the relative velocities with reference to the blades and steam jets.

In the diagrams Figs. 10 to 16 the turbine rotors of the different types are taken with blade speeds of 500 feet per second and an expansion of the steam from 165 pounds absolute to 1 pound absolute.

In the diagram of the De Laval turbine (Fig. 10) it will be seen that the jet of steam has a residual or leaving velocity after passing the wheel of 3200 feet per second, which results in a failure to abstract the full energy of the jet proportional to the square of such residual velocity. In order that one row of impulse blades such as obtain in this example might extract the maximum energy from the expansion of the steam from 165 pounds to 1 pound absolute, it would be necessary to have a blade speed of 1730 feet per second.

In the Rateau machine (Fig. 11) the residual velocity is 2880 feet per second, representing an amount of energy unabstracted by the turbine proportional to the square of this residual velocity.

If additional stages were added, this residual velocity could be abstracted without change in the blade speed, or the number of stages could be kept the same by increasing the blade speed to 1000 feet per second.

In the Curtis turbine, by subdividing the impulse elements into two, three, or four rows of moving blades per stage the same jet velocity may be used with a blade speed of 500 feet per second, with leaving losses as shown in the diagrams Figs. 12 to 14 inclusive.

It will be noted, however, that in the four-division stage extreme velocities are encountered, as in the De Laval wheel.

These high steam velocities are, as in the Rateau turbine, materially reduced by diminishing the stage division and increasing the number of stages (Fig. 15). This system presents probably the best development of the subdivided multiple-stage impulse turbine; but for a complete machine there are difficulties to contend with in the maintenance of proper steam distribution through the later stages. Considering, however, the first stage, of two subdivisions by itself, the advantage of this type of element is apparent. Comparing, for instance, the first stage expansion with that of a similar expansion arrangement in a

FIG. 12.

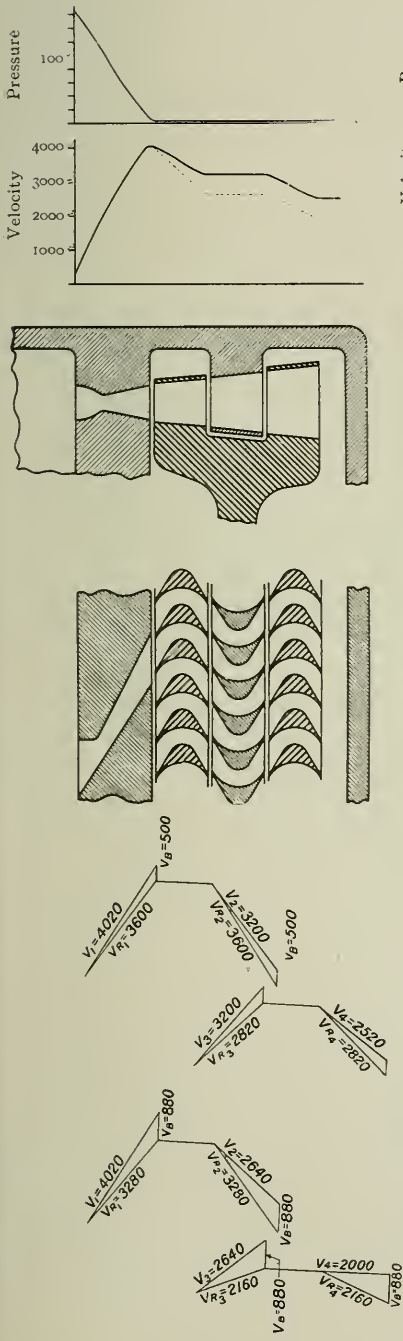

Pressure
100
Velocity
4000
3000
2000
1000
$V_B=500$
$V_1=4020$
$V_{R_1}=3600$
$V_2=3200$
$V_{R_2}=3600$
$V_B=500$
$V_3=3200$
$V_{R_3}=2820$
$V_4=2520$
$V_{R_4}=2820$
$V_B=880$
$V_1=4020$
$V_{R_1}=3280$
$V_2=2640$
$V_{R_2}=3280$
$V_B=880$
$V_3=2640$
$V_{R_3}=2160$
$V_B=880$
$V_4=2000$
$V_{R_4}=2160$
$V_B=880$

FIG. 13.

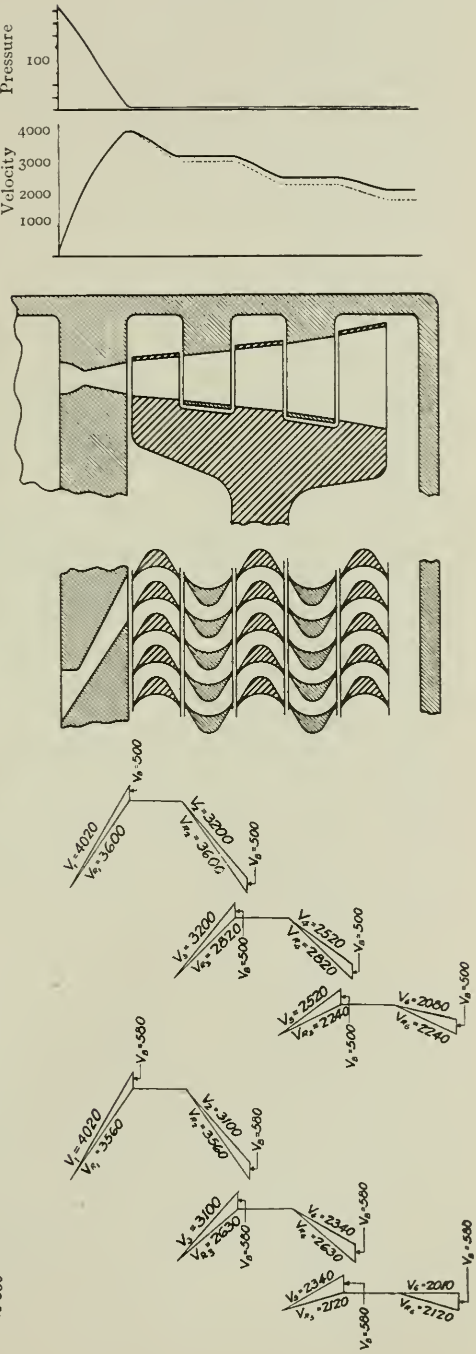
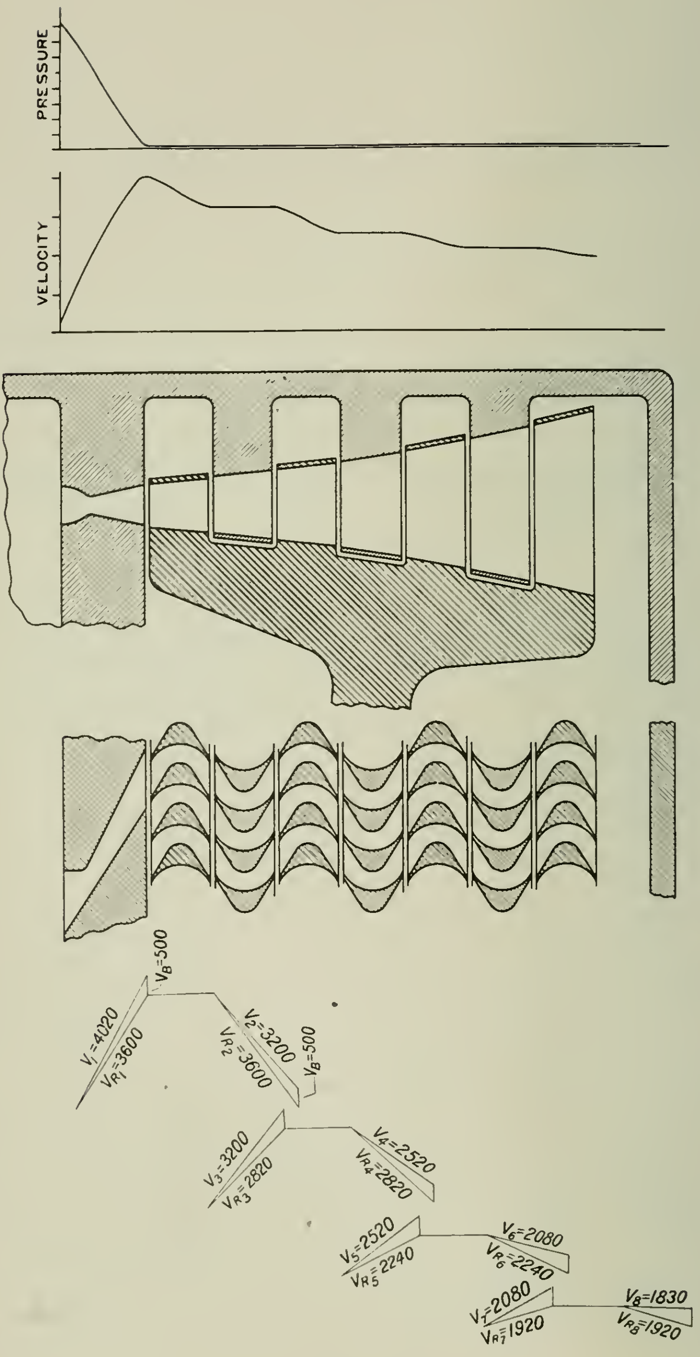
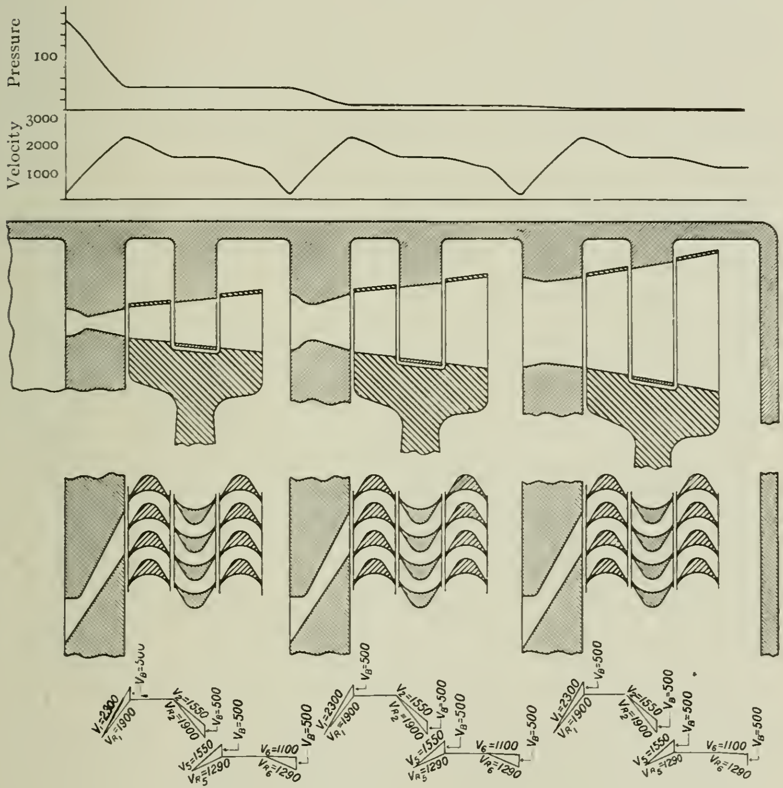

Pressure
100
Velocity
4000
3000
2000
1000
$V_B=500$
$V_1=4020$
$V_{R_1}=3600$
$V_2=3200$
$V_{R_2}=3600$
$V_B=500$
$V_3=3200$
$V_{R_3}=2820$
$V_B=500$
$V_4=2520$
$V_{R_4}=2820$
$V_B=500$
$V_5=2520$
$V_{R_5}=2240$
$V_B=500$
$V_6=2080$
$V_{R_6}=2240$
$V_B=500$
$V_B=580$
$V_1=4020$
$V_{R_1}=3560$
$V_2=3100$
$V_{R_2}=3560$
$V_B=580$
$V_3=3100$
$V_{R_3}=2630$
$V_B=580$
$V_4=2340$
$V_{R_4}=2630$
$V_B=580$
$V_5=2340$
$V_{R_5}=2120$
$V_B=580$
$V_6=2010$
$V_{R_6}=2120$
$V_B=580$

FIG. 14.


PRESSURE
VELOCITY
$V_B=500$
$V_1=4020$
$V_{R_1}=3600$
$V_2=3200$
$V_{R_2}=3600$
$V_B=500$
$V_3=3200$
$V_{R_3}=2820$
$V_4=2520$
$V_{R_4}=2820$
$V_5=2520$
$V_{R_5}=2240$
$V_6=2080$
$V_{R_6}=2240$
$V_7=2080$
$V_{R_7}=1920$
$V_8=1830$
$V_{R_8}=1920$

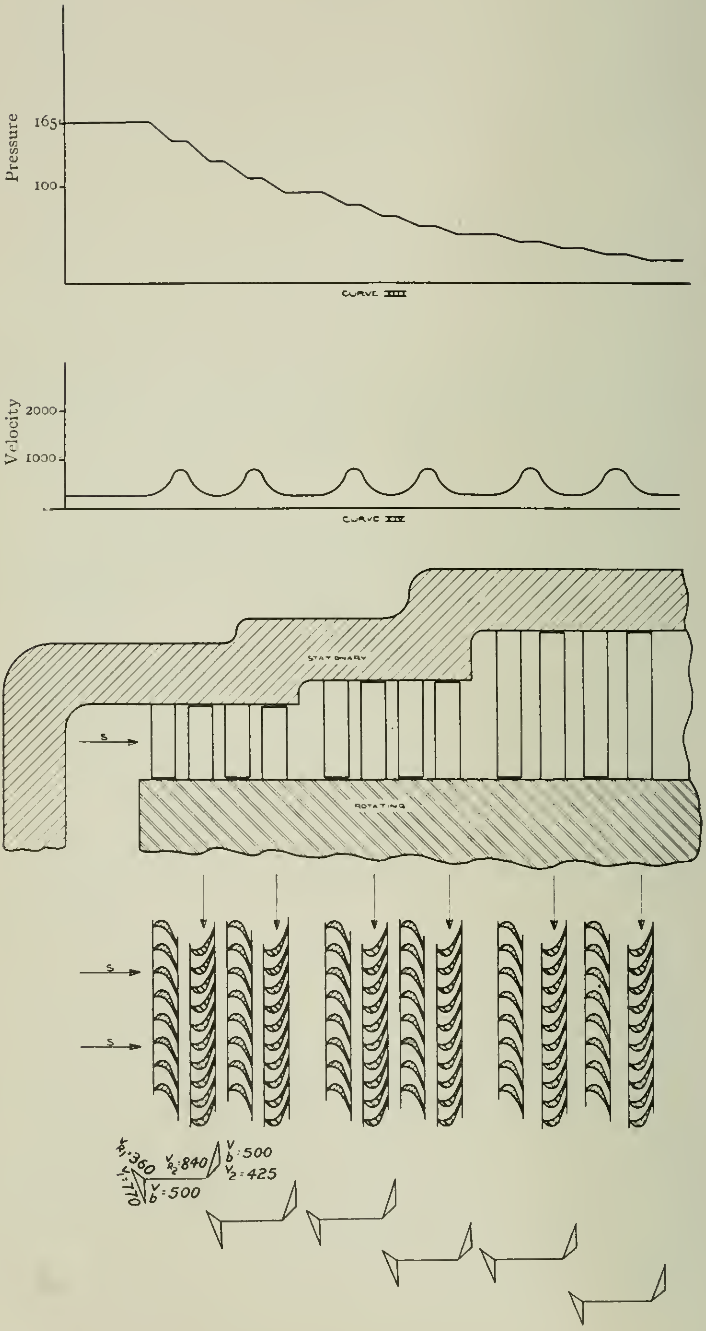
Rateau turbine, it can be shown that four individual Rateau stages are required to do the same work as this single subdivided two-row stage (assuming, of course, the same blade speed, viz., 500 feet a second, and the same pressure drop, 165 to 50 pounds absolute).

FIG. 15.



In the Parsons turbine the process of subdividing the steam expansion (as illustrated in Fig. 16) resolves itself into a relatively large number of rows of blades. An important result secured by this subdivision is the uniformly low steam velocities through the turbine. When velocities of 1000 to 2000 feet per second are encountered throughout the Rateau and Curtis turbines the corresponding velocities in the Parsons machine will vary from 150 to 1000 feet per second.

FIG. 16.


Pressure
165
100
CURVE XIII
Velocity
2000
1000
CURVE XIV
STATIONARY
S
ROTATING
S
S
$V_{R1}=360$
$V_1=770$
$V_b=500$
$V_{R2}=840$
$V_b=500$
$V_2=425$

As friction losses are a function of velocity, this relatively low velocity is an important point, and probably to a large degree accounts for the high efficiency of this system.

It is evident from the foregoing that the application of a turbine design to commercial use must embody a knowledge of the properties of steam and its co-relation to the mechanical structure of the machine.

While the pressure-volume diagram is important in the design of piston engines, it has little use, except by comparison, in the determination of the action of steam in the turbine.

The entropy-temperature diagram and the conversion of pressure to velocity under adiabatic expansion, together with the co-relation of heat drops, form the basis of turbine calculations.

The development of the turbine has therefore led to a closer study of the properties of steam, and by experimental work and mathematical deduction the physical properties of both saturated, wet and superheated steam have now been determined with certainty and precision, so that computations based on these show satisfactory concordance.

These principles and the physical laws governing the properties of gases and steam have been shown in Appendix I, from which, with experimental knowledge and calculation, an admirable set of tables on the properties of steam has been compiled by Professor Peabody. From such tables various charts have been plotted, to facilitate calculation, of which Fig. 17 is a good example.

From these tables and charts, for any difference in pressure, superheats, or qualities of steam, the B. T. U. drop, entropy, velocity, quality, specific volume, and energy may be obtained for adiabatic expansion of steam. With the above outline of the elementary principles in turbine design the more recent developments may be discussed as follows:

DE LAVAL TURBINE.

The early trials of the De Laval turbine led to an extended investigation into the proper design of steam nozzles to convert to the best advantage pressure into velocity. To De Laval is due the credit of the design of the expanding nozzle which has been found necessary in expanding steam in one stage from a relatively high to a relatively low pressure. De Laval's turbine, as has been pointed out, consists of a single row of blades which absorb the velocity obtained by a complete expansion in a single nozzle or a group of nozzles. In order, therefore, to absorb the energy due to the velocity of a jet issuing from the nozzles, it is necessary to have a blade speed somewhere approximating one-half of the velocity of the steam issuing from the nozzle, and where the steam is expanded through a relatively wide range of pressures it becomes impracticable, mechanically, to construct a turbine which with one row of blades will give sufficient blade speed to extract with maximum efficiency the energy from the steam.

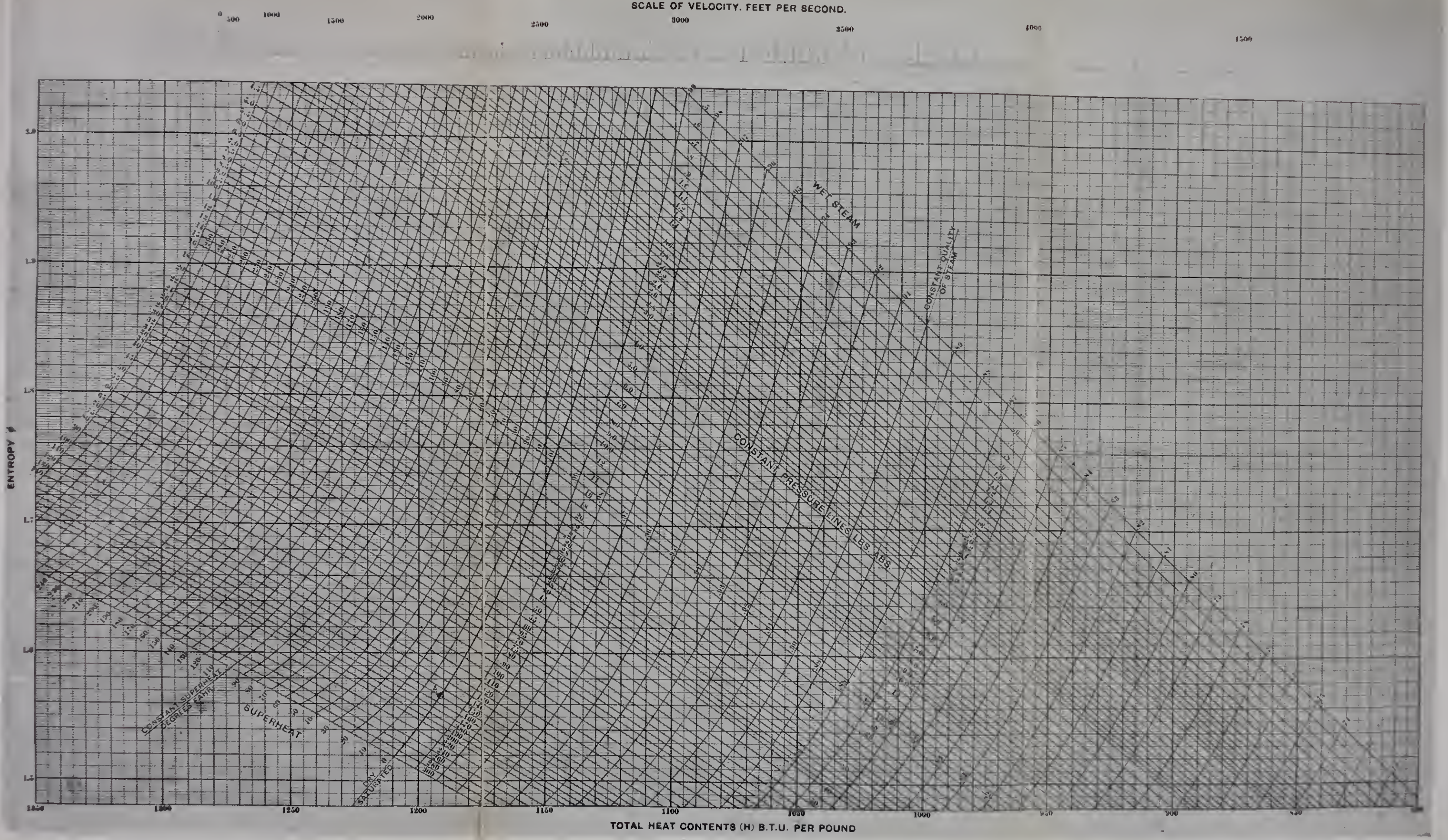
On account of the very high speeds, therefore, at which these turbines operate, the development of the De Laval turbine has been closely associated with the construction of disks or wheels of maximum strength. A discussion of the simpler cases of the stresses due to centrifugal forces in disks and drums is shown in Appendix II, from which it may be seen that the speed at which the blades, carried on these disks, may move limits their height, if the stresses in the disk are to be kept within reasonable limits.

The commendable feature in the De Laval turbine itself is its simplicity. To utilize the high rotative speeds to advantage commercially, however, it is necessary to supplement the turbine with suitable reduction gearing so that the turbine unit, consisting of turbine and gear, must be, for the sake of comparison, taken together, when its advantages and disadvantages are put side by side with the Curtis, Rateau, or Parsons turbine.

On account of the very high speeds at which the De Laval turbine operates, the wheels or disks require very careful designing, and have in recent developments of this machine taken two forms, as illustrated in Figs. 18 and 19. When the design in Fig. 18 is used, there is forced into the bored hub of the wheel, by means of a nut (as shown in the illustration), a thin steel bushing, which bushing is forced on the shaft and pinned in place as shown, before its application to the wheel. This type of wheel has been used in the smaller sizes, but a more recent development has resulted in the design shown in Fig. 19, principally for the

Fig. 17.

ENTROPY-HEAT CHART OF STEAM.



reason that a disk or a wheel of the disk type, in which there is a hole at the centre, is not more than half as strong as one without a hole.

It will be seen that the form of disk used has a decreasing

FIG. 18.

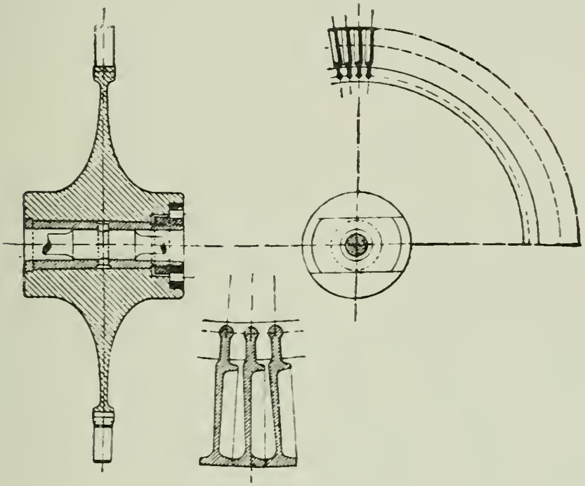
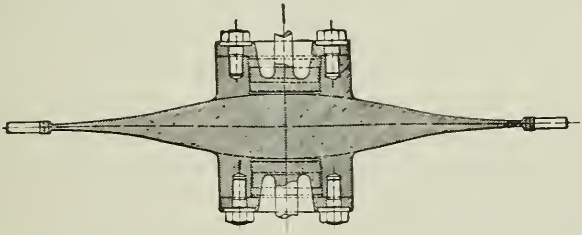


FIG. 19.



De Laval turbine wheel with and without hole in centre, and blading details.

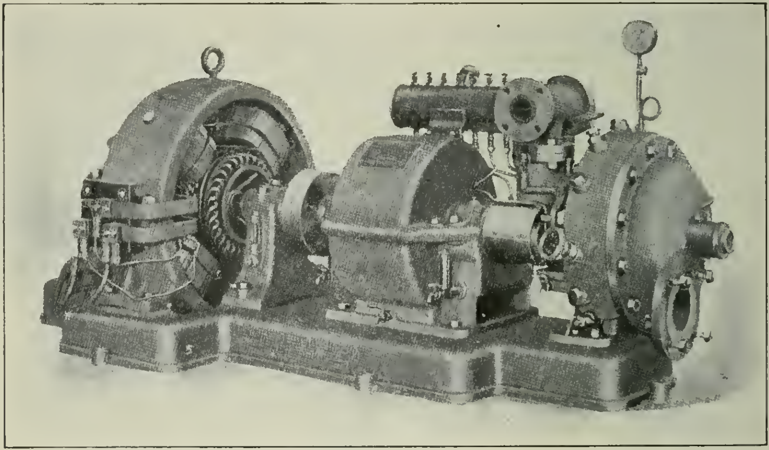
section toward the rim, the proportioning being obtained by designing the disk to have equal unit stresses throughout.

Weakening the wheel at the rim is resorted to as a good method of providing for abnormal stresses that might result in case of the failure of the governor to control the speed, and the wheel is purposely grooved near the rim so that, should the wheel burst, it will burst at the section where the stresses per unit of area are about 50 per cent. larger than at any other point on the wheel, rather than near the centre, where the damage from failure might be much greater.

Owing to the high stresses encountered in this type of turbine the diameters of the wheels are relatively small, and the materials used exceptionally good.

The following table gives a good idea of the relative proportions of several different De Laval machines:

Fig. 20.



20-horsepower De Laval turbine generator.

Horsepower	5	30	100	300
Revolutions per minute	30,000	20,000	13,000	10,000
Diameter to centre of blades, inches	3.94	8.86	19.68	29.92
Blade speed, feet per second	516	775	1115	1305

Fig. 20 is an illustration of a 100-kilowatt De Laval turbogenerator, from which may be seen the method of arranging the nozzles around the periphery of the turbine wheel. The nozzles are provided with hand valves by which they can be closed when the turbine is running at light loads. In this manner some of the nozzles are cut out, and relatively high efficiency may be obtained at light loads. Nozzles are the only parts of the De Laval turbine which are required to be changed with changing conditions of pressure, quantity of steam, or vacuum.

As the quantity of steam flow is proportional to the differences of pressure on either side of the nozzle, the areas of the cross section of the nozzle at the throat and at the mouth, and therefore its divergence or taper, are determined by the difference of pressure required in each case.

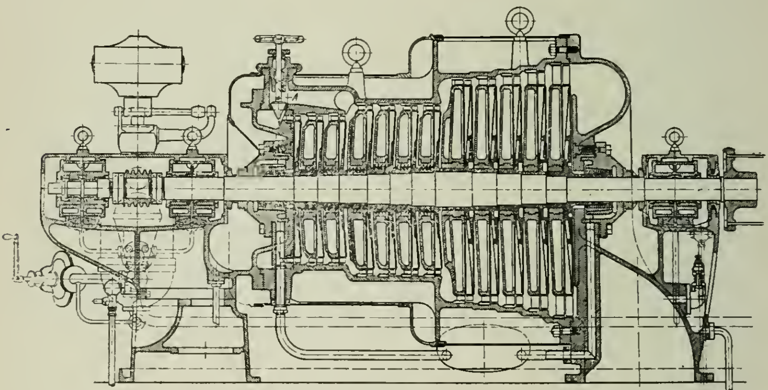
For the same output more steam is required at low pressure than at high pressure, and sometimes the turbine is fitted with two sets of nozzles, one of high back-pressure suitable for non-condensing purposes, and one for low back-pressures suitable for condensing purposes.

Owing to the high blade speed required in the De Laval turbine, a substantial blade fastening is required. The blades are made of drop forged steel and have bulb shanks fitted to suitable slots in the wheel, as illustrated in Fig. 18. The shrouding of the blades is integral with them. It is exceedingly difficult to construct a high-speed wheel so perfectly balanced that its centre of gravity will coincide with the geometric centre of the shaft with which it rotates. To overcome this difficulty, the De Laval turbine is constructed with a long, slender shaft which, as the speed of the wheel increases, yields somewhat and allows the latter to assume its own position of rotation about its centre of gravity. The difficulties surmounted in balancing these high-speed wheels may be better appreciated by the statement that the weight of one ounce attached at the circumference of the wheel of a 300-horsepower turbine will produce an unbalanced centrifugal force of nearly 2700 pounds.

As has been previously shown, it is necessary, with a De Laval construction, to properly extract the energy of a steam jet due to an expansion from 165 pounds to 1 pound absolute, to have a blade speed of approximately 1730 feet per second, and on account of the mechanical difficulties involved it has been necessary to sacrifice some efficiency to bring the turbine within practical mechanical construction. It will also be apparent that the capacity of the De Laval turbine is proportional to the amount of nozzle area available, and that such nozzle area is limited by the periphery of the disk and the height of the blades. Also, as the height of the blades increases, the load on the disk rim increases, so that a point is reached beyond which the stresses in the disk become impracticable; thus the capacity of the De Laval turbine is limited by the size of the wheel permissible and by the length of blade that can be used, with due regard to proper stresses in the disk, which limitations have resulted in the construction of the De Laval type of turbine for small powers, and then only by supplementing the turbine with gearing to reduce the high rotative speeds to commercial proportions.

The developments of the De Laval turbine which have borne an important part in the general construction of modern machines have been brought about by the necessity for research (1) in the efficient design of nozzles, (2) the mechanical construction of disks rotating at high speeds, (3) the fastening of impulse blades to properly resist high centrifugal forces, and (4) the construction of double opposed helical gears to reduce to commercial proportions the high rotative speeds necessary for a single-disk turbine.

Fig. 21.



Rateau turbine. Built by Engine Works, Oerlikon, 1903.

The proper proportioning of the De Laval nozzles is quite important in obtaining the maximum efficiency. Also, it can be shown that the blade angles may be made proper only for one condition of velocity ratios and angles of steam jet and blade.

It is a fact, however, that the De Laval machines of small capacity show good efficiency, compared with other types.

The advantages of this type of machine are: (1) simplicity, requiring only one disk and one row of impulse blades; (2) the absence of packing of any form to prevent the leakage of steam past the turbine elements.

The disadvantages in this type of machine are: (1) necessity for high blade speed to efficiently extract the energy in the steam; (2) on account of the high rotative speeds, the requirement of high-class materials and the necessity for careful designing to provide for the high stresses in the revolving parts; (3) the limited capacity of the machine, due to the limitation of the blades on account of the centrifugal forces; (4) necessity of reduction gearing in all cases; and (5) medium efficiency.

RATEAU TURBINES.

While the principle of the Rateau turbine is very old, to Professor Rateau is due the credit for its successful commercial development. The general principles of this multicellular type have been shown in the description of Fig. 11, and its construction was principally brought about by the desirability of dispensing with reduction gearing to bring the shaft speed within practical commercial limits.

Fig. 21 illustrates the general construction of this type of turbine as manufactured some few years ago.

This turbine consists essentially of mounting on a through shaft a series of disks which carry at their periphery a row of impulse blades. This series of wheels is mounted in the cylinder casing, which has diaphragms located between the successive disks of the spindle, with suitably-arranged packings between the spindle and the diaphragms. In the diaphragms are carried the nozzles which serve to expand the steam successively, the velocity of which expansions is absorbed by the rotating blades on the several disks.

One of the first machines of this character constructed consisted of 25 stages, and, to mechanically accommodate the length of the machine, was divided into a high- and low-pressure cylinder, as illustrated in Fig. 22.

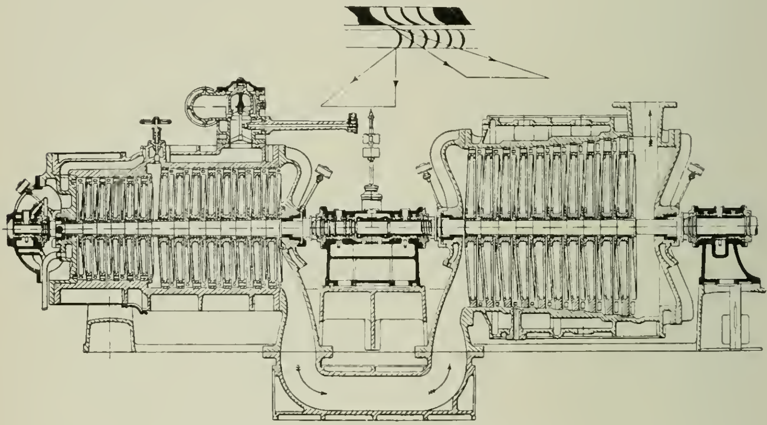
The large number of disks is employed to keep the peripheral speed of the blades rather low, so that simple construction of the impulse wheels could be resorted to and ordinary commercial materials utilized.

With this construction the energy due to the expansion of steam over wide ranges of pressure may be efficiently extracted.

On account of the blade speed being very much lower than that required in the De Laval turbine, the fastening of the blades to the disks and the construction of the disks themselves do not require the careful design or construction that obtain in the De Laval machine. It is also practicable, on account of the slower speed of the disk and blades, to very materially increase the disk diameter and also the blade length, resulting in the construction of a machine of very much greater capacity than would be possible with the De Laval turbine.

The nozzles in the Rateau construction are housed in the diaphragms and occupy only such portion of the periphery of the diaphragms as is required for the passage of the proper amount of steam from stage to stage. The increase in blade heights and space occupied by the nozzles on the periphery of the diaphragms admirably takes care of the increasing specific volume of steam during the expansion from stage to stage.

FIG. 22.



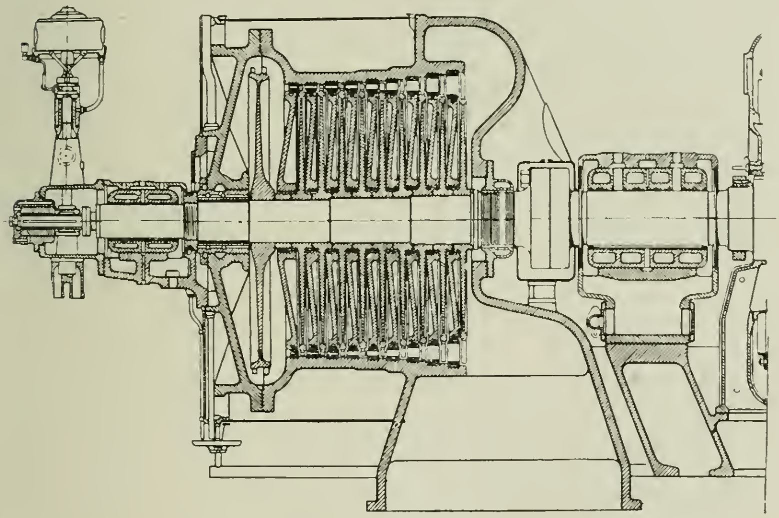
Rateau turbine, built by Sautter Harle, 1902.

The construction of these turbines is, however, expensive on account of the large number of rotating wheels and their corresponding diaphragms, with the necessity of close clearance or some kind of packing between the diaphragms and turbine spindle to prevent leakage of steam from stage to stage, and the recent developments in the Rateau turbine have led to an increased blade speed, thus materially shortening the machine by reducing the number of stages required for complete expansion.

As in the De Laval turbine, the necessity for proper nozzle and blade design in the Rateau turbine is apparent; in fact, owing to the multiplicity of stages, these two elements of the turbine require the closest attention to obtain the maximum efficiency; likewise, it is essential to prevent leakage of steam from stage to stage, which problem is not encountered in the De Laval construction. It is also apparent that with the disk construction in the multicellular type it is necessary to add weight to the spindle to secure that rigidity which will prevent undue bending moments on the turbine spindle, thus involving the necessity for packing at larger diameters between the various stages of the machine, with the consequent increase in loss by leakage.

By increasing blade speeds a shortening of the machine may be accomplished, which results in a lighter spindle with less distance between the bearings, and consequently a less bending moment to disturb the proper balance of the spindle while rotating. To further accomplish this shortening in the machine the firms building the Rateau turbine have resorted in the first stages to the Curtis wheel, thus replacing several of the Rateau elements, even with some slight sacrifice in the efficiency. Fig. 23 represents a construction of this kind.

FIG 23.



A. E. G. turbine, 1906.

The replacement of several of the Rateau stages by the Curtis element also has the advantage of materially reducing the pressure and temperature which enter the main casing of the machine, diminishing the probability of undue distortion of the cylinder and spindle.

The advantages of the Rateau turbine as obtained by the multicellular construction are: (1) reduction of speed to commercial limits as regards the application of the turbine to driving electric generators; (2) the reduction in blade speeds, resulting in the construction of disks from ordinary commercial steel and the mounting of the blades on these disks in a simple and effective manner; and (3) the increase in the diameter of the machine to permit of large capacities by accommodating a large number of nozzles around the periphery of the diaphragms, and allowing longer blades to be used without exceeding safe limits in the matter of blade stress in the disk, due to centrifugal force.

The disadvantages in the Rateau turbines are: (1) the necessity for packing along the shaft between the stages; (2) requirements of through shaft construction on which disks with holes are mounted; and (3) the necessity for nozzle control in the various stages for obtaining high economies at light loads, thus increasing the complicacy of the governor and control mechanism, or the sacrifice of economy to avoid such complication.

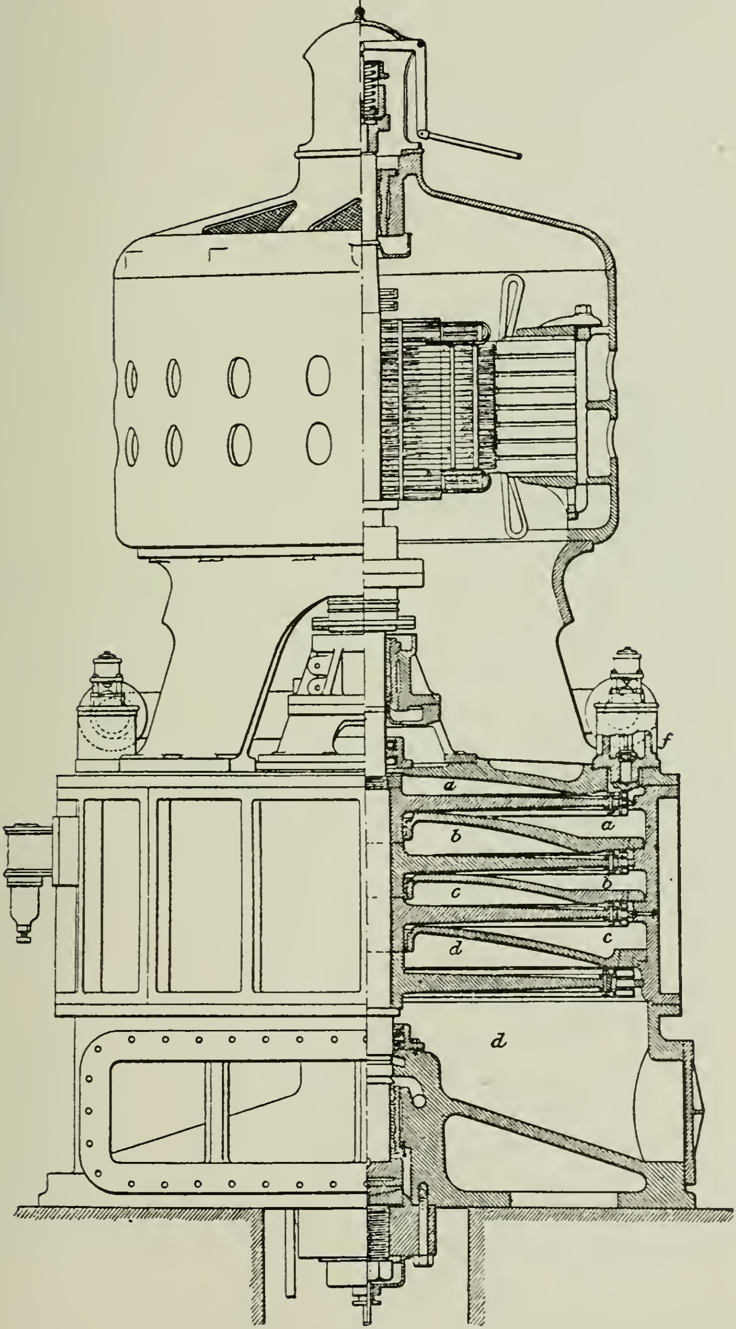
CURTIS TURBINES.

In the recent development of the Curtis turbine the tendency has been to recede from three or four to two moving rows of blades per stage, on account of better efficiency resulting from the latter construction.

Each stage of the Curtis turbine usually contains one wheel carrying two, three or four moving rows of blades, and between the successive stages is interposed a diaphragm similar to the construction followed in the Rateau turbine. The general construction of the machine is shown in Fig. 24. The steam, entering the nozzles of the first stage, is expanded to high velocity, the jet first impinging on the first moving row of blades, through which it passes to the stationary row, whose function it is to redirect the jet to the second row of blades, and so on. There is, therefore, per stage, one more row of moving blades than stationary blades, and each stage, therefore, contains three or more rows.

Like the Rateau turbine, the Curtis machine has partial ad-

FIG. 24.



Vertical Curtis turbine (about 1902)

mission in the high-pressure stages which allows better proportioning of the nozzles and blading; also, since the steam admission only covers a small part of the periphery of the wheel in the high-pressure stages, it is not necessary to continue the stationary row of blades beyond a distance much greater than that occupied by the mouth of the nozzles.

As has been shown previously, the object of the fractional extraction of velocity in the different stages of the Curtis turbine is to increase, for a given blade speed, the exit velocity from the nozzle, and consequently the absorption of a larger amount of energy per stage than obtains in the Rateau machine, blade speeds being equal. Consequently, in the expansion of steam through a given range of pressure, less stages in the Curtis turbine are required than in the Rateau turbine, resulting in a cheaper construction and a shortening of the machine.

The pressure of the steam in each stage is the same in all parts of the chamber, because the drop in pressure occurs almost entirely within the nozzles; but, since the drop in pressure per stage is greater than in the equivalent Rateau turbine, the difference in pressure from stage to stage is proportionately greater. It therefore is essential to prevent the leakage of steam from one stage to another past the diaphragms, which results in the necessity for suitable packing between the diaphragms and the spindle.

As leakage from stage to stage results in a loss in efficiency, the diameter of the shaft is made as small as practicable and the packing as good as may be to prevent these leakage losses.

The efficiency of the turbine depending, as it does, both on the conversion of pressure into velocity through the nozzles and the absorption of such velocity by the blading per stage, it is apparent that the Curtis turbine requires careful designing in the proportioning of nozzles for best efficiency, and proper blade angles and passages in the three, five, or seven rows of blades per stage.

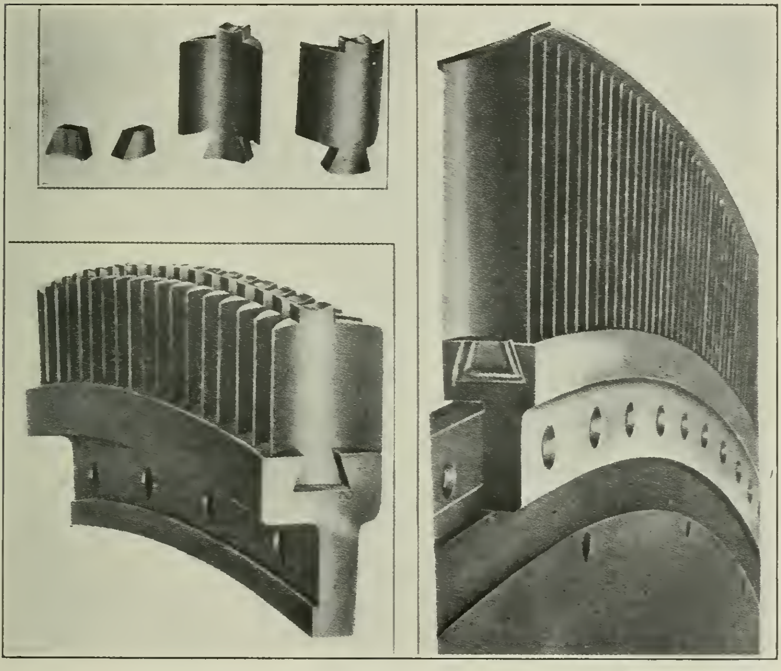
In fact, the lower efficiency found in practice from utilizing more than two moving rows of blades per stage has led, in general, to the abandonment of the three, four, or more moving rows of blades per stage, except in certain marine constructions and in turbines of low power, where mechanical or other considerations predominate over the desire for best efficiency.

The blade wheels are usually made of forged steel disks carrying the blades in dovetailed grooves, as shown in Fig. 25. In the larger machines a built-up blade-wheel construction is resorted to, as shown in Fig. 26.

The principal development in this turbine has been carried on by the General Electric Company in America, by the British Thompson-Houston Company in England, and by the Allgemeine Elektricitäts Gesellschaft in Germany.

In the Curtis and Rateau turbines the adoption of higher blade speeds as the design developed resulted in reducing the number of stages, thus reducing the cost of manufacture and increasing the economy.

FIG. 25.

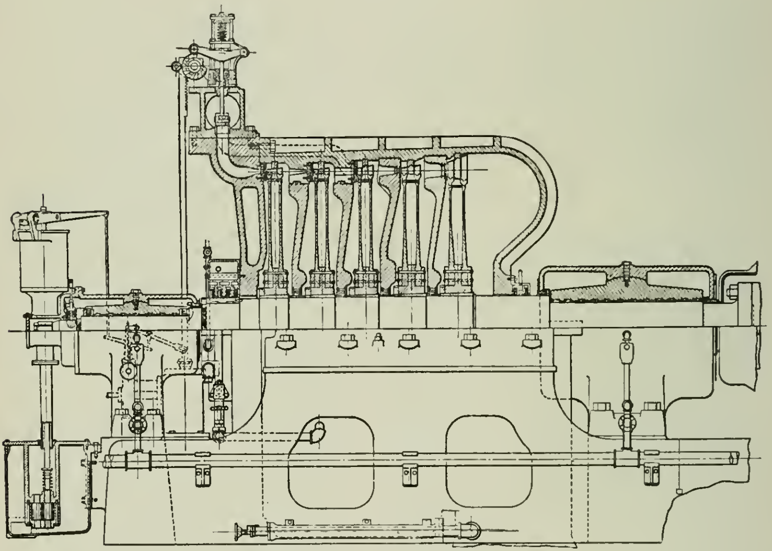


Recent Curtis turbine. Blading structure. (Dovetailed roots.)

The Curtis turbo-generator units of relatively large capacity as built in this country were, until the last few years, constructed with vertical shafts, but recent practice has modified to advantage the construction to the horizontal type of machine, which has generally been followed by the Parsons and Rateau turbines since their commercial introduction.

The advantages of the Curtis turbine are: (1) its adaptability and simplicity to the construction of turbines of small capacity where efficiency may in a measure be sacrificed for simplicity. Thus, for non-condensing service a small Curtis turbine consisting of one stage with triple velocity extraction or three rows of moving blades gives a fairly good economy with reasonable rotative speed, as compared with the De Laval turbine, which latter would, under similar conditions, require a reduction gear; (2) the reduction of pressure and temperature of steam passing a Curtis stage results in less severe conditions for the turbine casing than with a Rateau turbine of equal blade speeds; (3) the reduction in the number of stages required for complete expansion, as compared with the Rateau turbine, results in a shorter machine and consequently a more rigid shaft construction, together with a simplification of the turbine elements.

Fig. 26.



Longitudinal section through a 3500-kilowatt horizontal Curtis steam turbine.

The disadvantages of the Curtis turbine are: (1) its inability to secure highest efficiency in the larger sizes; (2) due to its cellular construction, the necessity for diaphragms and stage packing at the shaft; (3) the necessity for disks with holes, on account of the through shaft construction, and by the necessity in the design for two moving rows of blades, additional weight imposed on the rim of the wheel, increasing the stresses in the wheel for a given blade height and blade speed, as compared with the single row of blades of the Rateau turbine; and (4) the necessity for nozzle control in the various stages, with its resulting complications where best efficiency is desirable at less than full loads.

PARSONS TURBINES.

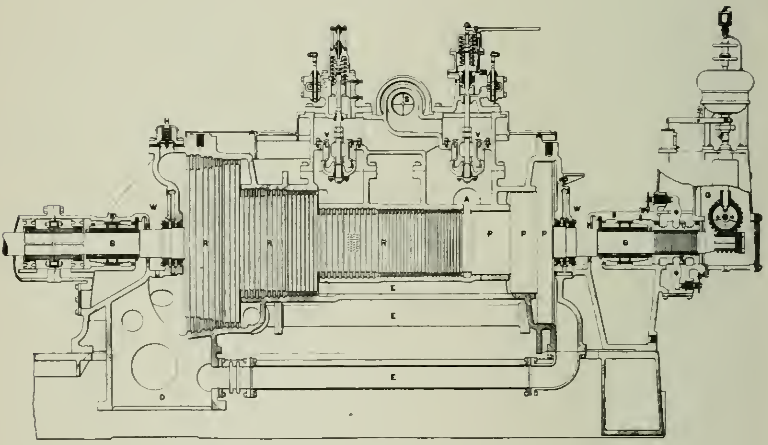
The Parsons type of turbine differs from other forms of turbines principally: (1) by the total admission of steam around the narrow space between the cylinder casing and the rotating drum, as compared with partial admission of steam to nozzles in the impulse turbines previously described; (2) the stationary and revolving blades of the Parsons turbine require an expansion of steam through the blades, resulting in a difference of pressure on either side of each row, while in the impulse turbine there is practically no difference in pressure on either side of the moving rows of blades in any one stage: in other words, the Parsons construction may be said to be made up of a series of stationary and rotating nozzles; (3) the governing control of the Parsons turbine must necessarily be done by throttling of the steam when light loads are required, while in the impulse turbine the governing can, on the first and succeeding stages, be controlled by cutting in-and-out nozzles or groups of nozzles.

The construction of the older machines built about ten years ago is illustrated in Fig. 27. On account of expansion of steam through the rotating blades it is apparent that an end thrust is set up in the spindle in the direction of the steam flow. One of the earliest developments in this type of turbine was the construction of a balancing piston to compensate this end thrust. It was necessary to so construct this piston that it would allow a relatively high speed of rotation without actually coming in contact with the turbine casing and yet be sufficiently tight to prevent the leakage of large quantities of steam past this piston into the lower stages of the turbine, with a resultant loss in efficiency.

This problem was effectually solved by Mr. Parsons with a multiple stage packing, which provides for small clearances between the successive stages of the packing and allows only such leakage of steam as can escape by the last stage after its specific volume has materially increased, due to a lower pressure.

On account of the specific volume of steam becoming greater as the expansion goes on in the turbine, requiring, therefore, larger openings through the blades, the lower stages of the Parsons turbine are increased in diameter to provide such opening as is required, and also to increase the blade speed where practicable, thus reducing the number of rows of blades required, since the velocity ratio of blade speed to steam speed is to be kept approximately constant throughout the expansion from stage to stage.[1]

FIG. 27.



Assembled section, typical Westinghouse-Parsons turbine.

The increase in drum diameter of the lower stages of the Parsons turbine requires a balancing piston similar in construction to the high-pressure barrel, and thus in Fig. 27, as there were three different drum diameters, there were provided three balancing pistons as shown, with equilibrium pipes between the end of each stage barrel and its corresponding balancing piston end.

As the spindle blades of the Parsons machine are mounted on a drum, and as there is a difference in pressure on either side of each row of blades, it is necessary to have the clearance at the ends of the blades small, to prevent undue leakage over their tips, such leakage vitiating the efficiency which could be obtained if it could be effectually prevented. It will be seen, therefore, that with a given clearance between the tips of the spindle blades and the cylinder or the cylinder blades and the spindle the leakage would, in general, be proportional to the height of the blade, so that if the blade lengths were small the efficiency of the high-pressure end of the turbine would be materially reduced.

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[1] By stages in the Parsons turbine is meant one row of stationary and one row of moving blades.

Early in the development of the Parsons turbine it appeared, therefore, that with commercial rotative speeds, without the use of gearing, it was necessary that the capacity of the turbine should be relatively large to give good efficiency, especially so as a reduction in blade speed, and consequently steam speed, to maintain a given velocity ratio would result in multiplying the number of rows of blades necessary to properly extract the energy from steam expanding through a given pressure range.

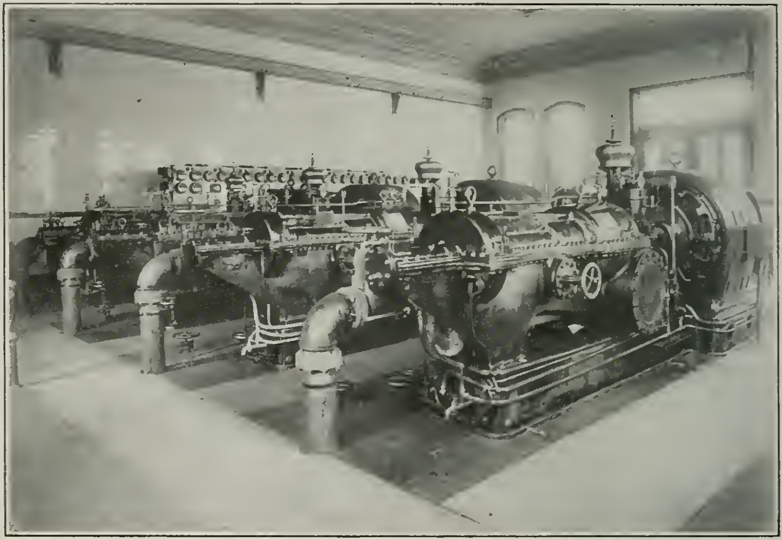
The energy in a steam jet being proportional to the square of its velocity, it can readily be understood that with half a given blade speed four times the number of rows would be required to extract the energy of a given expansion. Consequently, with small powers, it would be necessary to lengthen the machine inordinately to get a proper proportion between the length of the blade and its clearance so that good efficiency could be obtained.

For many years, therefore, the pure Parsons turbine has been confined to designs where relatively high powers are required. As Parsons turbines were designed some ten or twelve years ago, even at powers of 300 or 400 kilowatts, the spindle and casing became quite long as compared with their diameters, and as the steam from the boiler was led directly into the initial stages of the turbine with full peripheral admission, and consequently at full temperatures and pressures, difficulties were encountered in the mechanical construction, due to the long, narrow cylinder and spindle and the relatively wide range of temperatures and pressures in such cylinder.

As the capacity of the turbine increased and the development in the electrical art permitted higher rotative speeds for the turbo-generator, the above condition was very materially bettered, and with the then moderate steam pressures and temperatures a satisfactory commercial construction of the Parsons turbine was developed.

Through the foresight of Mr. George Westinghouse, The Westinghouse Machine Company became the first licensee under the Parsons patents in 1895, and began the commercial exploitation of this type of machine in America some three years later. Innumerable experiments were carried on by Mr. Westinghouse to determine the best blading proportions for turbines, and a general investigation into the turbine art as it was at that time developed.

FIG. 28.

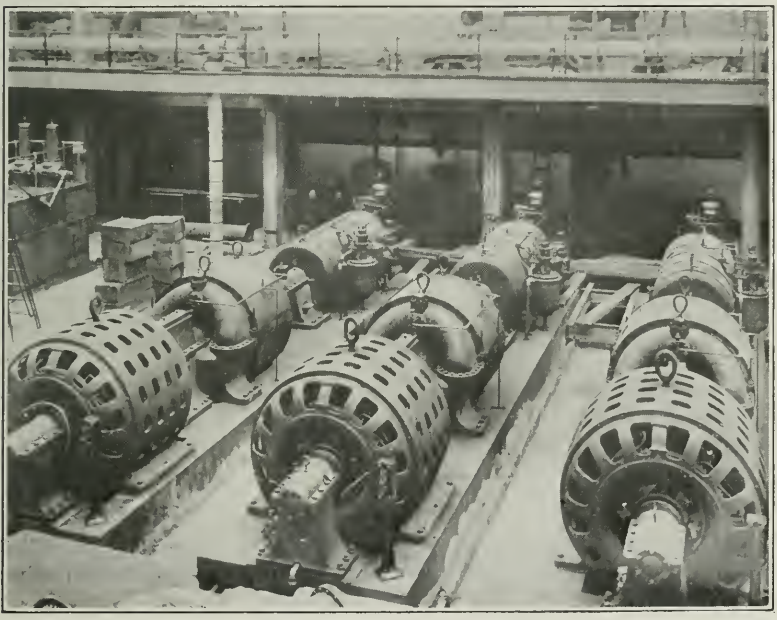


Power plant of Westinghouse Air Brake Company, Wilmerding, Pa.

On account of difficulties encountered in the design of long, slender cylinders, the early Parsons machines were made by dividing the complete expansion into two parts housed in separate cylinders. This overcame the difficulty experienced with the single cylinder machines until the capacity demanded by large turbo-generator units of high rotative speeds allowed the blade speeds to be sufficiently increased to shorten the turbine, and by increasing the diameter of the spindle to stabilize the mechanical construction so that the complete expansion could be carried out in one casing.

Fig. 28 shows a 400-kilowatt alternating current turbo-generator operating at 3600 revolutions per minute, built by The Westinghouse Machine Company and put into service at the Westinghouse Air Brake Company's plant at Wilmerding, Pa., in the latter part of 1899. Three similar units were built at the same time, and all four have been in continuous service to date.

FIG. 29.



Interborough Rapid Transit Company, New York City.

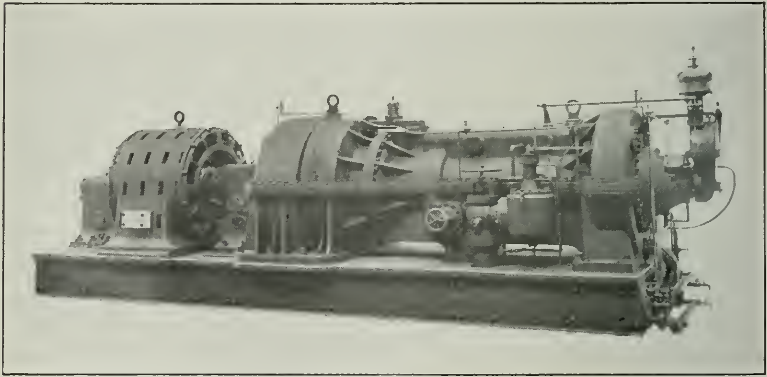
Fig. 29 shows three early 1000-kilowatt turbines of the two-cylinder type built in 1903 and still in service at the Interborough Rapid Transit Company's power plant in New York. These machines operate at 3600 revolutions per minute.

Fig. 30 shows the first large capacity turbine, built in 1900 for the Hartford Electric Light Company. This machine had a capacity of 1500 kilowatts, driving an alternating current generator at 1200 revolutions per minute.

Modifications in the mechanical construction of these turbines constitute the development in the Parsons type.

The advantages in the Parsons type are: (1) ease of construction; (2) the high economy obtained when operating conditions are suitable for proper proportioning of the blading; (3) ability to carry variable loads with good economy; and (4) adaptability to highest efficiency in operating when applied in large sizes.

FIG. 30.



1500-kilowatt turbine, Hartford.

The disadvantages in the Parsons type are: (1) loss in efficiency due to the necessity of blade-tip clearances, especially in machines of small capacity; and (2) difficulty in construction with the use of high-pressure and high superheated steam where long spindles and cylinders are required, due to slow rotative speeds or small capacities.

(*To be continued*)

Sources of Nitrogen. P. NITSCHE. (*Zeit. Angew. Chem.*, xxv, 2058.)—This is a summary of the existing sources of nitrogenous manures. There is need to enrich the soil with a carbohydrate nutrient so as to afford a cheap source of energy for the nitrogen-fixing bacteria. Waste sulphite-cellulose liquors, neutralized with lime so as to be slightly alkaline, are suggested as well adapted for this purpose; they contain a variety of directly available carbohydrates, as well as lignin substances. Such an application of these liquors would solve the problem of their disposal without polluting the rivers.

CHEMICAL PRODUCTION OF LIGHT.[1]

BY

WILDER D. BANCROFT,

Professor of Physical Chemistry, Cornell University.

For many years the firefly has been an object of admiration and envy to the chemist. The firefly produces light in a very efficient way. The spectrum of the emitted light consists of a narrow band in the yellowish-green portion of the visible spectrum, apparently unaccompanied by any emission in all the ultra-violet or ultra-red portions of the spectrum. As yet, the chemist cannot duplicate this result in spite of the fact that the light of the firefly is due to chemical action. When oxygen is absent, no light is given out. The light is not necessarily connected with the life of the firefly. The dry, powdered, abdominal material of the insects can be kept for as much as two years and will then emit light if moistened and exposed to oxygen. If the chemist could duplicate the abdominal material in the laboratory, he would have a substance which could be made to emit light having the same characteristics as the light emitted by the fireflies.

The chemist cannot do this as yet, and it is not necessary that he should try to, because there are undoubtedly other substances which would be easier to make and which would work equally well. The problem is to find out what these other substances are. There are certainly two ways of attacking a problem like this. One method has been made famous by Edison, and consists in trying every conceivable substance to see which one will be satisfactory. While this method has worked well with Edison in many cases, at any rate up to a certain point, it has not been a striking success in the hands of others, and it is not a method which appeals to a college professor. The Edisonian method is one extreme, and the other extreme is the professorial method. I cannot apply my own name to it, because it was carried to perfection long before I was born. The professorial method, as applied to our problem, consists in studying the way in which light has been produced from primeval times to the present, after which one would naturally discuss the whole theory of the production of light. This method has the advantage of enabling one to write an incredible number of papers without much effort. It is also possible to drop the subject whenever it becomes too difficult; according to Mr. Edison, this is what usually happens.

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[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, December 12, 1912; based on papers read before the Eighth International Congress of Applied Chemistry in New York, September, 1912.

The professorial method is the one that I am going to consider, though I shall not go back so far as to quote from a paper that I think I once read, on the kind of oil used in the lamps in the hanging gardens of Babylon. At the present day, artificial illumination is caused chiefly by heated solids. In the case of the incandescent lamp, this is obvious; but there might be some question about light from gas or oil.

This point has been discussed by Mendeleeff,[2] from whom I quote:

" Flames are of different degrees of *brilliancy,* according to whether *solid* incandescent particles occur in the combustible gas or vapor, or not. Incandescent gases and vapors emit but little light by themselves, and therefore give a paler flame.[3] If a flame does not contain solid particles, it is transparent and pale, and emits but little light.[4] The flames of burning alcohol, sulphur, and hydrogen are of this kind. A pale flame may be rendered luminous by placing fine particles of solid matter in it. Thus, if a very fine platinum wire be placed in the pale flame of burning alcohol—or, better still, of hydrogen—then the flame emits a bright light. This is still better seen by sifting the powder of an incombustible substance, such as fine sand, into the flame, or by placing a bunch of asbestos threads in it. Every brilliant flame aways contains some kind of solid particles, or at least some very dense vapor. The flame of sodium burning in oxygen has a brilliant yellow color, from the presence of particles of solid sodium oxide.[5] The flame of magnesium is brilliant from the fact that in burning it forms solid magnesia, which becomes white hot, and similarly the brilliancy of the Drummond light is due to the heat of the flame raising the solid non-volatile lime to a state of incandescence. The flames of a candle, wood, and similar substances are brilliant, because they contain particles of charcoal or soot. It is not the flame itself which is luminous, but the incandescent soot it contains. These particles of charcoal which occur in flames may easily be observed by introducing a cold object, like a knife, into the flame.[6] The particles of charcoal burn at the outer surface of the flame if the supply of air be sufficient; but, if the supply of air be insufficient for their combustion, the flame smokes, because these unconsumed particles of charcoal are carried off by the current of air."

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[2] The Principles of Chemistry, I, 176 (1891).

[3] All transparent substances which transmit light with great ease (that is, which absorb but little light) are but little luminous when heated; so also substances, which absorb but few heat rays, transmit few rays of heat when heated.

[4] There is, however, no doubt but that very heavy, dense vapors or gases under pressure (according to the experiments of Frankland) are luminous when heated, because, as they become denser they approach a liquid or solid state. Thus detonating gas is brightly luminous when exploded under pressure.

With incandescent solids, the intensity of the light is a function of the temperature, increasing rapidly as the temperature rises, and being independent of the nature of the solid if this is so arranged that it gives what is known as black body radiation,—in other words, if the conditions are such that no light can be reflected by the incandescent solid. This condition is not fulfilled strictly with ordinary illuminants; but the error is not of any serious importance in most cases. With temperature radiation, as it is called, the ratio of the visible radiations to the invisible radiations increases with rising temperature, and consequently we get the maximum efficiency at the highest temperature. Since the osmium, tantalum, and tungsten lamps have been developed in consequence of a clear understanding of this principle, it seems probable that we are approaching the limit of efficiency which can be reached in this way.

It seems probable now that the greatest progress is to be made by turning to other methods of producing light and by taking the modest firefly as our model. A step has already been made in this direction. The Moore light, for instance, and the flaming arc are cases where the light is not purely a function of the temperature. By putting suitable salts in a Bunsen flame or an alcohol flame we get an emission of light which varies with the specific substance used and which is not solely a function of the temperature. Addition of sodium salts causes a yellow flame, while we get a red one with strontium salts and a green or blue one with copper salts. This is not a case of cold light in the popular usage of the word; but it belongs under this head theoretically.

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[5] [This statement is undoubtedly wrong.—W. D. B.]

[6] If hydrogen gas be passed through a volatile liquid hydrocarbon—for instance, through benzene (the benzene may be poured directly into a vessel in which hydrogen is generated)—then its vapor burns with the hydrogen and gives a very bright flame, because the resultant particles of carbon (soot) are powerfully ignited. Benzene, or platinum gauze, introduced into a hydrogen flame may be employed for illuminating purposes.

The forms of luminescence which are not strictly temperature radiations have been classified by various people under the following heads:

Photoluminescence,
Thermoluminescence,
Pyroluminescence,
Electroluminescence,
Cathodoluminescence,
Anodoluminescence,
Chemiluminescence,
Crystalloluminescence,
Triboluminescence,
Organoluminescence.

When light stimulates a substance to emit light, we call it photoluminescence. If the luminescence lasts an appreciable length of time after the exciting light is cut off, we speak of phosphorescence, whereas we usually speak of fluorescence if the emission of light stops apparently at the same moment that the exciting light is cut off. By thermoluminescence we mean the light that is often emitted by phosphorescent substances when heated gently. Pyroluminescence refers to the light emitted by flames in so far as this is not due to the incandescence of solids. Flame spectra come under this head. Electroluminescence is the term for luminescence produced by the passage of an electric current through a gas. Cathodoluminescence is the luminescence produced by cathode rays when impinging on a solid or liquid, while anodoluminescence is the corresponding luminescence produced by canal rays. Chemiluminescence has been used hitherto solely for those cases where nobody could deny that the light must be due to chemical action. The light emitted during the oxidation of an alkaline pyrogallol solution is a typical instance of chemiluminescence in the narrow sense of the word. Crystalloluminescence is the word used when light is emitted during crystallization from solution, while triboluminescence is used for the light emitted when crystals are crushed. Organoluminescence is the luminescence produced by bacteria, marine organisms, luminous worms, flying insects, etc.

When one glances over this imposing list of terms, it is difficult not to be impressed by the wealth of knowledge which these terms seem to connote. A closer examination shows that this classification is based solely on the methods of producing light and not at all on the actual way in which light is produced. We should not be very much impressed by a man who classified fires under the headings: sulphur-match fires; safety-match fires; flint-and-steel fires; friction fires; lightning fires; spontaneous-combustion fires; crossed-wire fires; overheated-flue fires, etc. This classification might be valuable to an insurance man, but it would not tell us much about the theory of fire. It would be more rational to classify as oil, gas, coal, and wood fires, for instance, while a more careful study would show that all ordinary fires came under the general heading of rapid oxidations. Similarly I intend to show that the ten different kinds of luminescence are all cases of chemiluminescence, of luminescence due to chemical action.

When a substance emits light for an appreciable time after it has been exposed to an exciting light, the very existence of a time factor shows that we are dealing with some sort of a chemical reaction, using the term in its broadest sense. Consequently, all cases of phosphorescence are due to chemical reaction. The same reasoning applies to the case of thermoluminescence so-called. Since most cases of phosphorescence can be converted into cases of fluorescence by raising the temperature sufficiently, and since some cases of fluorescence have been converted into phosphorescence by adding gelatine, etc., to the solution, it seems reasonable to conclude that the difference between fluorescence and phosphorescence is a difference in relative reaction velocities. I am inclined to lay stress also on another argument. Since there is no known way of converting monochromatic light of one wave-length directly at ordinary temperatures, by reflection or refraction, into light of any other wave-length, it follows that we must have some chemical action taking place whenever luminescence of any wave-length is produced at ordinary temperatures by the action of light of another wave-length. The only reason for putting in the limitation in regard to ordinary temperatures is to head off the possible case where one would have temperature radiations due to the heating action of the incident light. Personally I am doubtful whether even this case is a real exception. It would not surprise me in the least to find that the so-called temperature radiation of solids was due to the giving off or taking up of electrons or something. My knowledge of the subject is not sufficient to enable me to reach a definite conclusion on this point, and consequently it will be simpler not to try to include this form of luminescence under chemiluminescence for the present.

In regard to pyroluminescence and electroluminescence I cannot do better than to base my argument on a quotation from Smithells:[7]

"When solids and liquids are heated beyond a certain temperature by an external source of heat, they become luminous, and the intensity of the light emitted increases very rapidly as the temperature is further increased. There is no reason to suppose that gases would behave differently except in degree, for, according to the kinetic molecular theory of matter, light should arise from molecular vibrations occasioned by molecular collisions. It is doubtful, however—whatever may be the case in celestial bodies—whether a gas has ever been brought by artifice into what may be called a state of purely thermal glow. The high transparency of gases to light is correlated to a very low emissivity: iodine vapor, which is an exceptional gas in its absorptive power, does indeed glow when heated in a glass tube, even when the walls are considerably below a red heat; but there is reason to believe that this glow is connected with the dissociation and recombination [8] of the atoms in the iodine molecule.

"Attempts to heat colorless gases, such as nitrogen, to the glowing point have given negative results.

"In almost every case a *flame is glowing gas*, and in view of the facts just recited we must add the qualification, so far as terrestrial conditions are concerned, that *the glow is the accom-*

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[7] Cf. Thorpe: Dictionary of Applied Chemistry, 2nd Ed. 2, 568 (1912).

[8] See especially Evans: *Astrophys. Jour.* 32, 1 (1910).

paniment of chemical change. It would be possible to refine upon this definition. A 'flame' of pure hydrogen in dustless air is invisible according to Stas, the radiation of short wave-lengths being wholly in the ultra-violet. Again, the glow observed during the decomposition of acetylene in a hot tube may be due wholly to the particles of liberated carbon, and in no degree to anything gaseous. But, speaking generally, the basis of flame is a glowing gas, and the exciting cause chemical action. This description would include ordinary hot flames and also flames of the kind called phosphorescent, which may be quite cold in the ordinary sense of the word."

The flame spectra of sodium chloride, strontium chloride, and cupric chloride cannot be temperature radiations from solids, because the temperature is the same in the three cases and yet the flames differ tremendously. They cannot be due to heated gases, because we have seen that it is probable that heated gases do not glow if no chemical action takes place. Consequently we conclude that pyroluminescence is a case of luminescence due to chemical action. In line with this is the fact that the carbon bisulphide flame is rich in ultra-violet rays in spite of its relatively low temperature. Since electroluminescence cannot be a temperature radiation from a heated gas, it must also be due to chemical reactions accompanying or following the electrical discharge.

In some cases, at any rate, the luminescence due to cathode rays or canal rays is similar to that produced by ultra-violet light or to that of flame spectra. For these cases we must therefore conclude that the cathode rays and canal rays produce light as a result of chemical action. Until there is some definite evidence showing fundamental differences between one case of cathodoluminescence and another we must postulate that all cases of cathodoluminescence or of anodoluminescence are cases of chemiluminescence. Under the circumstances it seems safe to assume that crystalloluminescence and triboluminescence are cases of chemiluminescence; and we know that the organoluminescence, so-called, of the firefly is due to chemical action. We therefore generalize that all forms of luminescence, with the possible exception of temperature radiations, are due to chemical action, using the term in its broadest sense.

The generalization that luminescence is always due to chemical reaction is not new. Pringsheim[9] made out a very strong case twenty years ago for the view that no gas emits light except as a result of chemical action. Armstrong[10] put forward the view, ten years ago, that luminosity and line spectra are the expression—visible signs—of the changes attending the formation of molecules from their atoms, or, speaking generally, that they are consequences of chemical changes. The difficulty is that the generalization has not been taken seriously by anybody, not even by Pringsheim himself. People speak of the carbon spectrum, the cyanogen spectrum, and the carbon monoxide spectrum, for instance, instead of speaking of the spectrum due to this, that, or the other reaction. There has been very little progress in the twenty years since Pringsheim's paper appeared.[11] This is not very surprising. People studied electromotive forces for a great many years before it became clear to them that they ought to speak of the electromotive force of a reaction[12] instead of the electromotive force of certain substances.

Having decided that luminescence is always due to a chemical reaction, we are confronted with two problems, as to the particular reactions in any given case, and as to what reactions give out light and the conditions under which this takes place. I shall consider these two problems separately.

Wiedemann and Schmidt[13] were unable to determine whether the emission of light was due to the decomposition of any given substance or to the reverse reaction. The trouble seems to have been that they wished to deduce this. Theoretically, one should always try to deduce things; but, practically, it often saves time to guess at the answer and then to test the guess. The South African war showed that a flanking movement might be very successful in cases where a frontal attack was foredoomed to failure.

Wilkinson[14] showed what reactions emitted light when cathode rays acted on certain salts by guessing at the reactions and then duplicating them chemically. Under the influence of the cathode rays, mercury bromide gives an orange glow, cuprous iodide a violet-red one, sodium chloride a bluish-white one, and potassium idodide a green one. He obtained the same type of light by letting the halogen react with the metal under suitable conditions. With halide salts there are not many reactions possible; but the problem becomes more complex when we come to sulphates. The light may be due, for instance, to the reaction between metal and oxygen, the conversion to sulphate not emitting light. The essential reaction may be conversion of oxide to sulphate, or it may be the reaction between metal and sulphate radical. At present the only way to distinguish between these hypotheses is to test each experimentally. This was done by Wilkinson in three cases, and the results are given in Table I.

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[9] *Wied. Ann.* 45, 429 (1892).

[10] *Proc. Roy. Soc.* 70, 99 (1902).

[11] Cf. however, J. J. Thomson: *Chem. News*, 103, 265 (1911).

[12] Haber: *Zeit. Elektrochemie*, 7, 443 (1901).

[13] *Wied. Ann.* 56, 243 (1895).

[14] *Jour. Phys. Chem.* 13, 691 (1909).

TABLE I.

Reaction	Light
$PbSO_4$ and cathode rays	blue
$Pb + O = PbO$	none
$PbO + SO_3 = PbSO_4$	white
$Pb + (NH_4)_2S_2O_8 = PbSO_4 + (NH_4)_2SO_4$	blue
$ZnSO_4$ and cathode rays	bluish-white
$Zn + O = ZnO$	green
$ZnO + SO_3 = ZnSO_4$	green
$Zn + (NH_4)_2S_2O_8 = ZnSO_4 + (NH_4)_2SO_4$	bluish-white
$CdSO_4 +$ cathode rays	yellow
$Cd + O = CdO$	yellow
$CdO + SO_3 = CdSO_4$	yellow
$Cd + (HN_4)_2S_2O_8 = CdSO_4 + (NH_4)_2SO_4$	white

From this table it is clear that the cathode rays break up lead sulphate and zinc sulphate into metal and the sulphate radical, and that the reverse reaction emits the light. In the case of lead sulphate this conclusion was confirmed by letting the cathode rays act for a long time, keeping the pump going all the time. The lead salt blackened, and a microchemical analysis showed the blackening to be due to metallic lead. So far as the color test goes, all we can say about cadmium sulphate is that the essential reaction is not that between the metal and the sulphate radical. Of the two other possible reactions we naturally select the one between cadmium oxide and sulphur trioxide, because it must take place before the oxide can be decomposed by the cathode rays. Wilkinson found that cadmium sulphate turns brown when exposed for a long time to the cathode rays while the pump is kept running. This brown product was identified microchemically as cadmium oxide.

So far everything has been satisfactory; but now we come to a difficulty. Wilkinson [15] found that a bluish light was emitted when sodium burned slowly in chlorine or oxygen, while the yellow flame, usually considered characteristic of sodium, was obtained when the combustion took place rapidly. There are thus two reactions which must be separated so far as possible. Both the bluish and the yellow luminescence are evidently due to the sodium, because they are modified but slightly by the nature of the acid radical, though Wilkinson noticed a trace of green in the flame when sodium burned in iodine. We shall come back to this point later. The best method of attacking the problem of the reactions giving rise to the two spectra is to find out under what conditions these two spectra are obtained.

When canal rays act on sodium chloride we get the yellow luminescence,[16] while cathode rays cause the bluish luminescence. Lenard [17] has shown that fused salts of the alkalies are luminescent, the sodium salts emitting a sky-blue light. This being so, one would expect to get a similar spectrum developed somewhere in the Bunsen flame, and this has actually been observed by Lenard in that portion of the flame separating the reducing zone from the oxidizing zone. Lenard also showed that the yellow flame is electrically neutral, while the bluish flame contains ions of some sort. As far as I can make out, the bluish luminescence is the same as the "continuous spectrum" of Kirchhoff and Bunsen.[18]

Bandrowski [19] has made experiments on the emission of light when sodium chloride is precipitated from aqueous solution by alcohol or by hydrochloric acid. When the precipitation takes place under suitable conditions of concentration and temperature, a bluish-white light is emitted. This is so like the bluish luminescence of sodium chloride that one is tempted to look upon the two as identical. Owing to the faintness of the crystalloluminescence, it is very difficult to be sure of this fact; but a confirmation, such as it is, may be found in the fact that Bandrowski obtained a greener light when potassium chloride was substituted for sodium chloride. This change is in the right direction, because Lenard found that fused potassium salts emit a green light and that a green light can be obtained with potassium salts in the Bunsen flame.

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[15] *Jour. Phys. Chem.*, 13, 703 (1909).

[16] Arnold: *Wied. Ann.*, 61, 326 (1897).

[17] *Drude's Ann.*, 17, 199 (1905).

[18] Kayser: Handbuch der Spectroscopie, 6, 34 (1912).

[19] *Zeit. phys. Chem.*, 15, 325 (1894).

This point has been taken up recently in my laboratory by Mr. E. F. Farnau,[20] who has confirmed and extended the experiments of Bandrowski :

"After half an hour's wait in the dark room until the eyes became sufficiently sensitive, 50 cc of saturated solutions of each of the salts, sodium and potassium chloride, bromide, and iodide were shaken with 50 cc of alcohol in a 100 cc graduate, and the glow appearing during precipitation was observed. In similar manner concentrated hydrochloric acid was employed as precipitant of the chlorides of sodium and potassium. The results as tabulated [in Table II] indicate the identity of the luminescence, whether produced by cathode rays, chemical combination, or precipitation."

TABLE II.

Color of Luminescence.

Salt.	Cathode ray	Chemical reaction.	Precipitation.
NaCl	bluish-white	blue	bluish-white
NaBr	bluish-white	blue-white	bluish-white
NaI	greenish-white	white (greenish?)	greenish-white
KCl	bluish-white	blue	bluish-white
KBr	blue	blue	blue
KI	green	greenish-white	green

In some cases there is a difference of opinion as to the actual color produced by the cathode rays. Thus Wiedemann and Schmidt[21] obtained a green light when potassium bromide was exposed to cathode rays. Beilby[22] also reports that potassium bromide gives a green light when exposed to the action of beta and gamma rays. Experiments made in my laboratory have led to somewhat different results. We find that cathode rays produce a bluish-white light with potassium chloride,[23] a blue light with potassium bromide, and a green light with potassium iodide. We have color photographs which show the differences very well. Since our results agree with those of Wiedemann and Schmidt for potassium chloride and potassium iodide, and since a trace of potassium iodide in potassium bromide would cause the green color, it seems to me quite probable that the alleged green light from potassium bromide was really due to an impurity of iodide in the salts used by Lenard, by Beilby, and by Wiedemann and Schmidt. The salts used by Beilby were undoubtedly impure, because he obtained a pink luminescence with potassium chloride, a result which nobody has confirmed. The question of impurities is of relatively little importance in comparison with the fact that any given sample emits substantially the same light when exposed to cathode rays, when fused, when precipitated from aqueous solution, when placed in the proper part of the Bunsen flame, and when formed by direct synthesis under suitable conditions.

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[20] Eighth Internat. Congress Applied Chemistry, 20, 127 (1912).

[21] *Wied. Ann.*, 56, 205 (1895).

[22] *Proc. Roy. Soc.*, 74, 511 (1905).

In the case of the fused salt and in the case of the precipitation of the dissolved salt, only one reaction seems possible. We are dealing with the change from the ion to the undissociated substance. There is, of course, no reason why the cathode rays should not disintegrate sodium chloride into sodium as ion and chlorine as ion. It has been proved that lead sulphate is decomposed into lead and the acid radical, and it is more in line with our usual way of looking at things to postulate SO_4'' as ion. The more serious difficulty comes when we consider the slow combustion of sodium in chlorine or oxygen. In order to bring these results in line with the others, we must assume that the reaction between sodium and chlorine or oxygen takes place in at least two stages, sodium as ion being one intermediate product. This is not really a far-fetched assumption. We make a similar one in regard to reactions of metals or gases in aqueous solution. It is a necessary assumption if we are going to consider the formation and decomposition of sodium chloride as a reversible process.

If the change from sodium as ion to the undissociated compound is the reaction which emits the bluish luminescence, we apparently have the change from electrically neutral sodium vapor to sodium as ion as the reaction causing the yellow light which we ordinarily associate with sodium. This would be a legitimate conclusion if we could be certain that there was only one reaction to be considered. This is not the case. Lenard [24] has shown that there are several sodium spectra, and the experiments of Wood and Galt [25] on the fluorescence of sodium vapor lead to the same conclusions. A good deal of work must be done before we can state specifically the reaction corresponding to each spectrum or spectrum series. On the other hand, there seems to be no danger of there not being enough possible reactions. J. J. Thomson [26] has recently shown that we have at least nine different substances when a current passes through oxygen gas: neutral molecular oxygen, O_2; neutral atomic oxygen, O; atomic oxygen with one positive charge, $O^{\cdot}$; atomic oxygen with two positive charges, $O^{\cdot\cdot}$; atomic oxygen with one negative charge, O'; molecular oxygen with one positive charge $O^{\cdot}_2$; ozone with one positive charge, $O^{\cdot}_3$; polymerized oxygen with one positive charge, $O^{\cdot}_6$; free negative corpuscles.

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[23] This was also noticed by Wiedemann and Schmidt.

When sodium burns slowly in chlorine or oxygen, the change from sodium as ion to the undissociated compound is the only reaction taking place with sufficient rapidity to cause the emission of light. When the combustion is more rapid, we get the emission of yellow light which corresponds to the second, as yet unformulated, reaction. The intensity of this light is relatively so high that it ordinarily masks the continuous spectrum,[27] having a maximum in the blue. If hydrochloric acid be passed into a sodium flame, the yellow color disappears and we get the continuous spectrum. A mixture of NaCl and NH_4Cl gives very little yellow to an alcohol flame.

The work of Pringsheim [28] brings out clearly the relation between the flame spectra of sodium salts and the combustion spectra. Pringsheim showed that the illuminating gas in the Bunsen flame reduced the sodium salts, and that the yellow light was due to the oxidation. Out in the oxidizing zone of the

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[24] *Drude's Ann.*, 11, 636 (1903).

[25] *Astrophys. Jour.*, 33, 72 (1911).

[26] *Chem. News*, 103, 265 (1911).

[27] Lenard: *Drude's Ann.*, 17, 208 (1905).

[28] *Wied. Ann.*, 45, 428 (1892).

Bunsen flame we have rapid combustion, and consequently we get the yellow light, just as we do when sodium burns rapidly in chlorine or oxygen. At the surface separating the reducing zone and the oxidizing zone we have the lowest rate of oxidation, and consequently we should expect to find, what Lenard actually found, the same luminescence which is obtained when sodium burns slowly in chlorine or oxygen. We are not limited now to the chemical reactions which were known twenty years ago, and we do not have to postulate a reaction between sodium and another chemical element in order to account for the yellow light. The value of Pringsheim's work consists in his conception that the reaction causes the light.

Earlier in this paper I stated that the bluish luminescence is modified but slightly by the nature of the acid radical. This is purely an empirical statement; but it is one which is made as a first approximation by all workers in this field. Thus Wiedemann and Schmidt [29] conclude from their work with cathode rays that "in general the color of the luminescence of salts of the same metal is the same. The acid radical has an effect only on the intensity of the light. That some salts of a given metal luminesce, while others do not, is probably an effect of the acid radical." Lenard [30] found that the light was usually dependent only on the metal and not on the acid.

Of course, the generalization that the luminescence of a salt under various conditions depends only on the nature of the metal can only be true when the light emitted by chlorine, oxygen, etc., is negligible. While this is ordinarily the case, Lenard found specific effects due to the acid in the case of phosphates and borates. "The phosphates and borates belong in a special class. In the case of the salts previously mentioned, the color emitted by the fused salt was determined by the metal alone. With the phosphates and the borates, the acid is not only a factor in determining the color of the emitted light, but it is the predominant factor. Potassium phosphate emits blue light in the reduction zone and green light in the oxidation zone; while white light is obtained in the fusion zone, presumably owing to the clouding. Precisely the same effects are obtained with phosphoric acid alone (I used metaphosphoric acid containing a little sodium). Potassium borate remained transparent and dark for a long while in the flame, but finally began to emit blue light. It was found, however, that by that time practically all the potassium had vaporized from the bead and that both the blue light and the green light could be obtained equally well with pure boric acid. Lithium borate and sodium borate also emitted blue light."

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[29] *Wied. Ann.*, 56, 205 (1895).

[30] *Drude's Ann.*, 17, 203 (1905).

Wiedemann and Schmidt's own experiments with cathode rays show that their generalization is only a first approximation. Thus they obtained a white luminescence with potassium chloride and a bright green one with potassium iodide; a yellow one with lead bromide and a beautiful green one with lead iodide. As has already been stated, we find that cathode rays cause potassium chloride to fluoresce bluish-white, potassium bromide bright blue, and potassium iodide bright green. We have not had time to go into this matter carefully, as yet; but it seems probable that the green color observed with some iodides may be connected with the fact observed by Salet [31] that there is a green color in the oxidizing zone when a mixture of hydriodic acid and hydrogen burns in the air. Salet showed the formation of iodic acid under these circumstances; but if the color is due to a reaction of the iodine, it might be obtained under other conditions. A careful quantitative study of luminescence will doubtless show slight differences due to each acid radical. It is quite possible that the specific effect due to chlorine has been overlooked, because it produces whitish light.

Trautz [32] considers all cases of luminescence during crystallization (crystalloluminescence) as cases of triboluminescence or luminescence produced by crushing crystals. In view of what we have seen of the relation between crystalloluminescence, luminescence due to cathode rays, luminescence due to combustion, etc., it is clear that the hypothesis of Trautz cannot be maintained in its present form. I see no objection to wording the hypothesis in another way. I should prefer to say that, in some cases, triboluminescence is the same as crystalloluminescence. When two crystals are rubbed together, one will become electrified positively and the other negatively. One way for this electrification to take place would be by a dissociation, sodium as ion going to one crystal and chlorine as ion to the other. A recombination, or an oxidation of the sodium, would then cause an emission of light which should be the same in quality as the light emitted under some other conditions. There is no difficulty about confirming this if we stick to sodium salts, because most triboluminescence is apparently bluish-white. Owing to the relatively faint light emitted as triboluminescence, it is very difficult to decide whether potassium iodide, for instance, gives a green light or the mercury halides an orange light. We hope to get definite evidence on this before long; but, for the present, a definite statement is not possible. In the case of sugar and substances of that type, luminescence in the Bunsen flame could not be the same as triboluminescence; but I should expect the triboluminescence to coincide in quality with the luminescence produced either by cathode or by the canal rays, as the case might be.

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[31] *Comptes rendus,* 80, 884 (1875).

[32] *Zeit. Elektrochemie,* 11, 307 (1905); *Zeit. phys. Chem.,* 53, 12 (1908).

Having shown how it is possible, in many cases, to discover what specific reaction is emitting light, we can now take up the second question and can ask what reactions give out light and under what conditions. The answer to this is very simple. All reactions tend to emit light, and all reactions do emit light when the reaction velocity is sufficiently high, though the absolute speeds necessary in any two cases may be very different. This is merely a further extension of conclusions previously reached by others. Trautz [33] pointed out that an extraordinary number of chemical reactions are accompanied by emission of light, and that the intensity of light increases with increasing reaction velocity. It is easy to show that some reactions emit no visible light under certain conditions but do emit light when the conditions are more favorable. Wilkinson [34] found that "bismuth, tin, zinc, and cadmium all give negative results when heated in a current of oxygen. However, when cadmium is heated with a blast lamp until it volatilizes, it combines with oxygen and burns with a deep-yellow flame to the reddish-brown oxide. Zinc, heated in the blast to boiling, burns with a green flame." Cases of this sort could be duplicated indefinitely. A very satisfactory experiment is to mix powdered calcium carbonate with red fire. It is very easy to arrange the proportions so that the red fire burns completely without showing any red.

Bandrowski [35] says: "I first studied the crystallization of sodium chloride, potassium chloride, potassium bromide, potassium sulphate, and potassium nitrate from aqueous solutions. I caused the crystallization to take place under all sorts of conditions: at different temperatures; by evaporating on the water bath, on the sand bath, or over a free flame; by sudden cooling (passing the supersaturated solution through a spiral tube which was kept very cold). In no case was I able to detect any emission of light.

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[33] Trautz, *Zeit. phys. Chem.*, 53, 1 (1905); *Zeit. Elektrochemie*, 14, 453 (1908).

[34] *Jour. Phys. Chem.*, 13, 704 (1909).

[35] *Zeit. phys. Chem.*, 15, 324 (1894).

"I accounted for this negative result by assuming that, under these conditions, the ions combined so slowly and over so large a space that the emission of light was too faint to be detected by the eye, more especially since a very intense light was scarcely to be expected even under the most favorable conditions. It became necessary, therefore, to do the experiments under such conditions that the forcing back of the dissociation would be practically instantaneous. It seemed to me that this could be done by adding a liquid which would be miscible in all proportions with water but which would precipitate these salts. Alcohol and aqueous hydrochloric acid are such liquids.

"The experiment confirmed my assumption, and I was able to obtain light effects which were fairly strong with some of the salts, provided the concentrations of the two liquids were adjusted carefully."

Miss Stevenson[36] found that there was no visible light emitted when quinine sulphate was dehydrated slowly, and that a photographic plate was not fogged by a month's exposure to slowly dehydrating quinine sulphate. Visible light is emitted if the dehydration takes place rapidly. There was a possibility that the wave-length of the light emitted during dehydration might be different when the dehydration was slow from that which was emitted when dehydration was rapid. If that were so, there should be a gradual change in the quality of the light if sulphuric acid, containing varying amounts of water, were added to the hydrated salt. This experiment was tried by Miss Stevenson. "The intensity of the light diminished as sulphuric acid, containing more and more water, was added to separate portions of hydrated quinine sulphate. No change in the color of the light could be detected. Moreover, the experiments of Nichols and Merritt,[37] who found that, with varying wave-length of exciting light, there was no change in the position of the wave-length of maximum density of fluorescent light, make a shifting of the wave-length of the light given off by quinine sulphate less probable."

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[36] *Jour. Phys. Chem.*, 15, 854 (1911).

[37] *Phys. Rev.*, 19, 18 (1904).

These experiments of Miss Stevenson are only qualitative and merely make it probable that the variation with varying speed of dehydration is solely in the intensity of the light. We have other evidence that the composition of the light emitted by any given reaction is practically constant. Pringsheim[38] says that in the case of all the non-luminous (faintly luminous) flames, in which the combustion products are chiefly carbon dioxide and water, the radiation seems to depend only on the chemical reaction. The radiation of all these flames seems to be independent of the temperature and to be the same qualitatively[39] and quantitatively[40] when the same amounts of water and carbon dioxide are formed. Fredenhagen[41] confirms this, for he finds that in the whole field of the water vapor spectrum the ordinary hydrogen flame and the oxyhydrogen flame emit practically the same amounts of energy, when referred to equal quantities of water, in spite of the fact that the temperature of the oxyhydrogen flame is approximately double that of the ordinary hydrogen flame.

In the case of the so-called temperature radiation from solids, the quality of the light changes with rising temperature. On the other hand, the change of the intensity with the temperature is described by a general formula applicable to all wave-lengths. If we omit this case, as before, we seem to be justified in concluding that a fairly definite spectrum corresponds to each definite reaction, and that any marked change in a spectrum indicates the occurrence of another reaction.

It is well known that the phosphorescent sulphides of zinc, calcium, strontium, and barium do not phosphoresce unless they contain traces of copper, bismuth, manganese, etc., and it is also well known that the color of the light emitted by the phosphorescing sulphides seems to be determined by the nature and amount of the salts of copper, bismuth, manganese, etc., Wilkinson[42] found that the sulphates of sodium, lithium, potassium, and zinc increase the phosphorescence of cadmium sulphate when exposed to cathode rays, but apparently without changing the quality of the emitted light to any appreciable extent. I interpret this to mean that these salts act as catalytic agents, accelerating the rate of reaction between cadmium oxide and sulphur trioxide, and thereby causing the emission of more light. In the case of the phosphorescent sulphides, the reaction which emits light must be a reaction of the salts of copper, bismuth, manganese, etc., while the sulphides of zinc, calcium, strontium, or barium act as a medium to permit dissociation, just as water does with salts.

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[38] *Wied. Ann.*, 45, 428 (1892).

[39] W. H. Julius, *Arch. nécrl.*, 22, 310 (1888).

[40] R. V. Helmholtz, Die Licht und Wärmestrahlung verbrennender Gase, 69 (1890).

[41] *Zeit. Elektrochemie*, 14, 458 (1908).

If sodium sulphate plays the part of a catalytic agent when cathode rays act on cadmium sulphate, it follows that a cadmium sulphate, which fluoresces but slightly at ordinary temperatures, should fluoresce more intensely at higher temperatures and should scarcely fluoresce at all at low temperatures. This experiment has been tried in my laboratory by Mr. E. F. Farnau.[43]

"The cathode tube used consisted of two parts, into the upper of which was sealed the disk cathode and ring anode, the lower part holding the salt. A two-cylinder Geryk oil-pump maintained the vacuum. The extremely pure salt was exposed in the tube to the cathode emanation and showed little or no luminescence at ordinary temperature. It was hoped that raising the temperature would produce cathodoluminescence. But here a difficulty arose: either due to slow expulsion of occluded gases in the salt or to adsorbed moisture in the glass, or to increased permeability of the glass to air at the higher temperature, the vacuum dropped off, as indicated by the decrease in the characteristic green fluorescence of the glass in the cold parts of the tube. This naturally precluded any possibility of success of the experiment.

"Since rise in temperature produced such disastrous effects, it was decided that the reverse could be tried. The purified salt was replaced by a well-dried commercial sample, which, under cathodo-excitation, glowed brilliantly at ordinary temperatures. All of the tube save about one-quarter inch of the bottom was wrapped with cotton gauze and jacketed in glass. Liquid air was poured on the gauze until it was saturated. The vacuum improved considerably, as evidenced by the increased cathodoluminescence both of the salt and the glass of the tube. When the vacuum was at its best, the salt, still at room temperature, was cooled by immersion of the bottom of the tube in liquid air. As the salt cooled, its luminescence decreased, as did that of the glass, until it finally became barely visible. The experiment was repeated a number of times, the salt being brought alternately to room temperature and to that of liquid air; the luminescence increased and diminished correspondingly. Similar results were obtained with potassium bromide, which ordinarily shows a bright blue cathodoluminescence."

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[42] *Jour. Phys. Chem.*, 13, 719 (1909).

[43] Eighth Internat. Congress Applied Chemistry, 20, 133 (1912).

One consequence of the theory which I have outlined is perhaps of importance for the production of cold light. If we knew what reactions took place in fluorescent solutions, and if we could cause these reactions to take place rapidly by some other excitation than light, we should have these same solutions fluorescing vigorously in the dark. It is along this line that a revolution in lighting will some day take place.

The general results of this paper are:

1. Photoluminescence, thermoluminescence, pyroluminescence, electroluminescence, cathodoluminescence, anodoluminescence, crystalloluminescence, triboluminescence, and organoluminescence are all cases of chemiluminescence, of luminescence due to and accompanied by chemical action.

2. In some cases of cathodoluminescence it is possible to give the chemical reactions taking place.

3. One should speak of the spectrum of a reaction and not of the spectrum of a substance.

4. Any marked change in a spectrum indicates the occurrence of another reaction.

5. The same bluish light is emitted: when sodium burns slowly in chlorine; when sodium chloride is fused; when sodium chloride is placed in the surface separating the oxidizing and the reducing zones of the Bunsen flame; when hydrochloric acid gas is fed into a sodium flame; when sodium chloride is precipitated from aqueous solution by alcohol or by hydrochloric acid; when sodium crystals are crushed.

6. The light effect due to the change from chlorine as ion to undissociated sodium chloride seems to be negligible for the present. More accurate measurements will undoubtedly show the existence of such a light effect.

7. Cathode rays excite the bluish luminescence in sodium chloride, and canal rays the yellow luminescence.

8. The bluish luminescence in the Bunsen flame is found where the rate of oxidation of reduced sodium salts is lowest, at the surface between the reducing zone and the oxidizing zone. The yellow luminescence is observed in the oxidizing zone, where the rate of oxidation is higher. This is in harmony with Pringsheim's experiments on the radiation of sodium.

9. The simplest assumption in regard to the reaction producing the yellow sodium flame is that it is due to the change from sodium to sodium as ion. This hypothesis is inadequate, because it does not take into account the other sodium spectra observed by Lenard and by Wood.

10. Under the influence of cathode rays potassium iodide emits green light. Part of this light is probably due to the iodine. It seems possible that the chlorine may be the cause of some of the white light observed with many chlorides.

11. While it is probable that the triboluminescence of potassium iodide is the same as the crystalloluminescence and the cathodoluminescence of this salt, the experimental evidence is as yet insufficient.

12. All reactions tend to emit light, and all reactions do emit light if the reaction velocity is sufficiently high.

13. The critical reaction velocity, necessary to the emission of light visible to the eye, may be very different with two different reactions.

14. The intensity of the emitted light increases with increasing reaction velocity.

15. The quality of the emitted light varies but slightly with the reaction velocity.

16. The sulphates of sodium, lithium, potassium, zinc, etc., increase the luminescence of cadmium sulphate when exposed to cathode rays chiefly by increasing the rate at which cadmium oxide and sulphur trioxide combine.

17. In the case of the phosphorescent sulphides of zinc, calcium, strontium, and barium, the reaction which emits light is one involving the so-called impurities—the salts of copper, bismuth, or manganese, for instance.

18. It is theoretically possible to stimulate the reactions causing fluorescence by other means than light.

CORNELL UNIVERSITY.

Diminishing the Loss of Metal in Brass-founding. F. BENSEL. (*Metallurgie,* ix, 523.)—The direct addition of zinc to melted copper in an electrically-heated crucible produced hardly any alloy, as the zinc volatilized and oxidized. Several attempts to substitute for the zinc an equivalent quantity of blende, the copper being in sufficient excess to form cuprous sulphide with the sulphur of the blende, and sodium sulphide being used as a flux, were also unsuccessful; the brass produced never contained more than about 12 per cent. of zinc, and great quantities both of copper and zinc were lost in the slag. Sodium and calcium carbonates used to flux the blende were also failures. Finally the metals were melted together in a closed egg-shaped furnace through the centre of which passed carbon electrodes joined by a rod of resistance carbon. The furnace could be rotated so as to agitate and mix the metals, and had a covered opening through which the alloy could be poured. There was practically no loss of zinc, and the resulting brass was almost exactly of the composition, 70:30, it was calculated for. The cost of melting a ton of brass was about $1.50 for power, in a furnace taking a charge of 50 kilos., and about 55 cents for resistance carbon. The saving in zinc, as compared with the ordinary method of manufacture, may be taken at 60 cents per ton of brass.

Electrical Separation of Tar from Coal Gas. A. H. WHITE, J. W. HACKER, and F. STEERE. (*J. Gas Lighting,* cxix, 825.)—An electric separator for separating the tar from crude coal gas by the action of a silent high-tension electric discharge was constructed of an iron cylinder, 12 inches in diameter and 20 feet long, having a tin can wound with cloth hung in the centre, to act as a positive electrode. The gas was treated at temperatures varying from 75° to 150° F. (24° to 65.5° C.), and it was found that the elimination of the tar was so complete that the gas leaving the separator appeared perfectly colorless and left only a faint brown stain on a piece of filter paper through which 1 cubic foot of gas was filtered. In one test the separator operated continuously for five hours upon gas at 154° to 130° F. (68° to 54.5° C.) generated from 400 pounds of coal, the ordinary condensers separating 12.8 pounds of tar and 12.2 pounds of water, and the electric separator effecting a further removal of 17.7 pounds of tar and 2.8 pounds of water. In some experiments the cloth became coated with tar, whereupon the discharge became disruptive and the separating effect was greatly diminished.

Aluminum Nitride. (*Eng. Pat.* 8349, 1912.)—Aluminum nitride is produced by heating a mixture of alumina and carbon, to which catalytic substances, such as metallic oxides, hydroxides, and carbonates, or metals are added, in a current of nitrogen to which varying proportions of free or nascent hydrogen are added.

A RADIOMETER ATTACHMENT FOR A MONOCHROMATIC ILLUMINATOR.*

BY

W. W. COBLENTZ, Ph.D.,
Associate Physicist, U.S. Bureau of Standards.

Having recently had occasion to design a radiometric attachment for a monochromatic illuminator (*e.g.*, Hilger's), a brief description is given herewith, thinking it might be of use to experimenters who are using light-stimuli.

At the present day visible and ultra-violet radiations are being used by chemists for producing photo-synthesis, by biologists who are investigating, for example, the effect of radiant energy upon lower organisms, by psychologists who are studying the effect of light upon the eye, and by physicists who are measuring the photo-electric effect of different parts of the visible and the ultra-violet spectrum.

In all cases it is desirable to know the energy value (mechanical equivalent) of the different wave-lengths used as stimuli; and it is, of course, usually desirable to reduce the energy of the different spectral regions to the same value. For this purpose it is necessary to use a radiometer which functions independent of the frequency of the stimulus. The most useful radiometer which requires but little care is a thermopile. The bismuth-silver thermopile [1] is much more sensitive than a commercial, iron-constantan thermopile, and it has been found useful in measuring light stimuli.

In the present design the bismuth-silver thermopile previously described is mounted securely in an air-tight metal box, *A*, fitted with a quartz window (Fig. 1). The thermopile is mounted upon an insulated support, *C*. The diameter of the bismuth wire is 0.1 mm., and the silver wire is 0.04 mm., as previously described. This metal case moves in vertical ways, which are attached to the spectrometer slit, *B*, by means of screws. When it is desired to measure the intensity of the emergent radiations the thermopile is lowered in front of the slit, *S* (see Fig. 1, "end view"). When it is desired to have the light pass out into space, or when it is desired to make any adjustments or test the calibration, the thermopile is raised above the slit.

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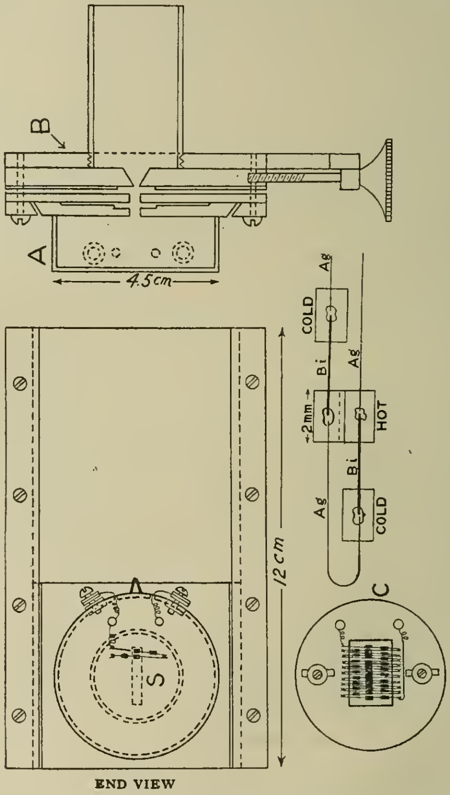
* Communicated by the author.

[1] Coblentz, Journal Franklin Institute, Dec., 1911. Bull. Bur. of Standards, 1912.

Owing to the extreme sensitivity of these thermopiles it is necessary to have the surroundings at a uniform temperature. For this reason the present design was evolved, hoping thereby to minimize the temperature changes which are encountered in moving the thermopile a great distance from the spectrometer slit. The thermopile is attached to a Thomson galvanometer.

FIG. 1.



In case the thermopile carriage is attached to the ordinary spectrometer slit as shown at *B*, the sloping parts of the jaws should be painted with lampblack. It is desirable to have the (blackened) flat side of the knife-edge face the spectrum, so that the spectrum may be cut off sharp, without passing into the V-shaped trough which is a source of stray light.[2]

WASHINGTON, December 27, 1912.

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[2] Since writing this, Adam Hilger, Ltd., has undertaken the construction of this attachment to go with his monochromatic illuminators.

RESISTIVITY OF A FEW METALS THROUGH A WIDE RANGE OF TEMPERATURE.*

BY

EDWIN F. NORTHRUP, Ph.D., and V. A. SUYDAM, B.S.
Members of the Institute.

THE following is a preliminary note and a partial report upon an investigation now in progress and which was begun by Edwin F. Northrup, January 11, 1911, and continued in cooperation with V. A. Suydam since January 1, 1912: The object of this investigation is twofold. First, to perfect a method whereby the resistivities of metals and alloys may be measured with ease, precision, and rapidity through a range of temperature between that of liquid air and a point a little below the boiling point of the substance in question; the same method to be applicable to molten salts. Second, to use this method for obtaining data on metals, alloys and molten salts, which boil under 1500° C., for plotting sets of curves relating the resistivity and temperature over a range of temperature of from 20° C. to near the boiling point of the substance in question.

The method for obtaining data on the metals is sufficiently perfected to permit of ready application (though improvements are being continually made), and the resistivity curves for half a dozen pure metals have been obtained with sufficient precision to make the authors feel justified in reporting upon them at this time.

The resistivity of any substance in the solid state depends upon its nature, the temperature, its purity, and, more than is generally supposed, upon its physical state. This last, in turn, depends upon its past history. If the substance assumes a liquid state, on the other hand, its past physical history is undoubtedly without influence upon its resistivity. Metals in the liquid state and at normal pressures may be expected to always assume the same resistivity when brought back to the same temperature, provided the chemical constitution remains fixed. If they do not return to the same resistivity, at the same temperature, when different samples of what is presumably the same substance are compared in their liquid states, then it may be assumed that the samples differ chemically. The perfection of a method which will measure the resistivities of molten metals at elevated temperatures with a precision comparable to that obtained in the measurement of mercury at ordinary temperatures ought to permit of a delicate discrimination respecting the chemical purity of the samples investigated.

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* Communicated by the authors.

Mercury can be obtained in its liquid state of great purity. It has a high resistivity, and this resistivity is a function only of the temperature, the past history of the liquid metal being entirely without influence. It is therefore, of all substances, the one which is apparently best suited to serve as a standard of resistivity. In our investigation all of our resistivities are referred to the volume resistivity of mercury. We have adopted the values of Kreichgauer and Jaeger, which are—expressed in microhms per centimeter-cube—94.073 at 0° C., 95.782 at 20° C. and 103.56 at 100° C.

Since the difficulties in the way of measuring the resistivities of most of the metals in the molten state have proven to be very great our efforts up to the present time have been concentrated chiefly upon perfecting our methods, and we have only attempted to make our measurements in a manner in which errors of the second order are neglected. Thus the cubical expansion (which is very small) of the container has been neglected. The samples selected have been such as could be obtained from reputable manufacturers, and no attempts have been made thus far to further purify the samples and to chemically analyze those which have been used. Up to the present time we have been satisfied with the attainment of a precision in which the errors in the resistivities of the metals in the liquid state should not exceed 0.25 of 1 per cent., and, for reasons which will appear later, a precision for the resistivities in the solid state in which the errors should not exceed 1 per cent. The precision of the rate of change of resistivities between any two temperatures, for which the material is either a solid or a liquid, is far better than the above. For these relative values the errors in our measurements probably do not exceed 0.04 of 1 per cent., and we believe that in many cases these errors are considerably less. It is our expectation that we shall be able eventually to compare the resistivities of all metals in the molten state, which melt under 1400° C., with an order of accuracy not far different from that obtained for a metal of large temperature coefficient at room temperature. The method by which the measurements were made has been planned with this precision in view. It is a new one in very many respects, and is being continually perfected with the progress of the work. For this reason we think it would be premature to describe the method at this time. We shall, therefore, defer any detailed description of the method to a later report when it is hoped that further progress shall have brought it more nearly to perfection. We may state in general, however, that the metal to be tested is placed, while molten, in a highly refractory container which does not react chemically with the metal to be tested at the highest temperature attained. Thus far no serious difficulty has been encountered in carrying the temperature, in the case of a metal like copper, to 1430° C. The upper limit possible is still to be ascertained. The measurements are made by a modified application of the Kelvin-double-bridge principle. One of the modifications permits the resistivities for a centimeter-cube to be read directly upon the bridge without calculation. An important feature of the method is that the current and potential terminals always consist of the same material as the substance being measured. The points where the potential terminals join the current terminals are at the same temperature as the section of the conductor being measured. This arrangement insures against chemical contamination. The resistivities are all referred to mercury at 20° C. and are expressed in microhms per centimeter-cube. The temperatures of the metals reported upon were measured, for temperatures above 200° C., by means of a carefully calibrated Pt vs Pt + 10 per cent. Rh thermocouple, and below this temperature with a mercury thermometer.

The data here reported upon refer to the following metals. The chemical analyses are those given by the makers upon the labels on the bottles:

I. *Mercury.*—The mercury used as a standard and for obtaining curve I was redistilled by Dr. G. A. Hulett and was pronounced by him to be very pure.

II. *Lead.*—The sample measured was obtained in the form of thin sheet from the Arthur H. Thomas Company. It was called "test lead" free from sliver.

III. *Cadmium.*—This metal was obtained in the form of sticks from the Arthur H. Thomas Company. The analysis and purity are not known to the writers.

IV. *Zinc.*—This metal was "Merck's reagent zinc" in drops free from arsenic, sulphur, phosphorus, iron and matter oxidizable by potassium permanganate.

V. *Tin.*—This metal was "Baker's analyzed," purchased in sticks. The analysis given on the label was:

Arsenic, trace.
Lead, 0.001 per cent.
Iron, 0.002 per cent.
Zinc, none.
Copper, none.

VI. *Bismuth.*—This metal was "Baker's analyzed" in lumps. The analysis given on the label was:

Lead, 0.003 per cent.
Copper, none.
Iron, none.
Arsenic, none.

VII. *Antimony.*—This metal was "Baker's analyzed." The analysis on the label was:

Iron, 0.015 per cent.
Copper, none.
Arsenic, trace.
Tin, none.
Zinc, none.
Lead, 0.001 per cent.

The curves given here are not originals, but much reduced copies of the originals which are drawn upon cross-section paper 20 inches wide with the inch divisions divided into tenths. In these copies the observed points are given only in the case of the curve for tin. They are, of course, given upon the original curves for all the metals, are equally numerous and lie equally close upon the curves as in the case shown for tin.

These curves, taken up in order, may be commented upon as follows: Curve I (Fig. 1) is for redistilled mercury. To obtain the resistivity in microhms add 90 to the numbers in the third column from the left. The boiling point of mercury at 760 mm. pressure is given as 356.7° C. Our measurement of resistivity is only carried to 295° C., or 61° C. under the boiling point. The reason for not going higher in temperature is the same one which has limited, thus far, the upper temperature of all our measurements. It was found in this and in the case of the other metals reported upon, that, at the upper temperature at which the measurement stops a bubble of vapor forms in the

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liquid column. The bubble rapidly expands if the temperature is further raised. A first indication of this phenomenon is a very sudden rise in the indicated resistivity being measured, and then, unless the temperature is very promptly lowered (and not always then), the indicated resistivity rises beyond the limit of the bridge and the circuit opens. The first suggestion is that the bubble so formed is some kind of gas. This hypothesis, however, seems to be excluded by the fact that when the temperature is lowered some 20° to 50° C. below the point where the sudden change in the indicated resistivity begins to take place the circuit is restored and the resistivity returns exactly to the same value at any given temperature. If the bubble which forms is due to the vaporization of a trace of impurity originally in the metal, then the return of the circuit and the original resistivity is readily explicable upon the assumption that the vaporized substance recondenses. The explanation is not tenable that the vapor is given off by the container itself or from its walls, for we found no such phenomenon to occur when the container was filled with molten copper at a temperature of 1430° C. Furthermore, there is no fixed temperature at which this formation of vapor occurs, appearing, for example, in the case of the sample of mercury at 295° C. and in the case of the sample of antimony at 915° C. The curve for the resistivity of mercury is regular and very slightly convex toward the temperature axis.

The resistivity increases from 95.78 at 20° C. to 105.5 at 120° C., or an increase of 10.14 per cent. in 100° C.

Curve II (Fig. 1) is for cadmium.

The boiling point of the metal is given as 778° C. The formation of a vapor bubble did not occur until the temperature was raised to 748° C., hence the resistivity of this metal is traced to within 30° C. of its boiling point.

The container is filled with the metal while molten, hence when the container cools down to a point where the metal solidifies a contraction or reduction in cross-section of the metal occurs which is not shared by the container. The resistivity measured is high in the solid state in the ratio of the cross-section of the metal in its liquid state to its cross-section in its solid state. As it is an easy matter to accurately determine the resistivity of the solid metal outside of the container, the method gives a means of deducing the shrinkage of a metal in passing from the liquid to the solid state. Let a curve be drawn parallel to the portion of the curve drawn from the observed readings which gives the resistivity of the metal in its solid state. If this curve is drawn through points which are assumed to give the true values of the resistivity of the metal in the solid state, then the ratio of the resistivity of the metal just after fusion to its resistivity just before fusion may be obtained by comparing the resistivity just after fusion is complete with the assumed true resistivity just before fusion begins. As no reliable data for the resistivity of cast cadmium were available, the ratio of the resistivity after fusion (33.77 microhms) to the resistivity before fusion (17.1 microhms, estimated) is taken from the curve as drawn. It is estimated at 1.97.

Curve III (Fig. 1) is for lead.

The curve for the solid state is slightly convex toward the temperature axis, and for the liquid state a straight line.

In this case no dotted line is drawn to represent the true resistivity of the metal in the solid state measured out of the container because the data have not been obtained by us, and no published values for lead which had been slowly cooled have been found. The resistivity just after fusion is 94.7 microhms. The resistivity just before fusion is not sharply defined because the change in resistivity in passing from a solid to a liquid is not abrupt but somewhat gradual. If we take 49.2 microhms as the highest value for the solid state, the ratio of the resistivity for lead just after fusion to the resistivity just before fusion is 1.92.

Paul Müller has determined[1] the resistivity of lead in the liquid state in the temperature range 327° C. to 1000° C. His value for the resistivity at 600° C. is 107.2 microhms, and our value at the same temperature is 107.2_5 microhms, a difference of less than 0.1 of 1 per cent.

Curve IV (Fig. 1) is for zinc.

All the remarks which apply to shrinkage in the case of cadmium apply equally in the case of zinc. A curve is drawn in dotted line parallel to the curve in full line to express the resistivity of zinc in its solid state. The curve is drawn through points at 18° C. and 100° C. The published value at 100° C.

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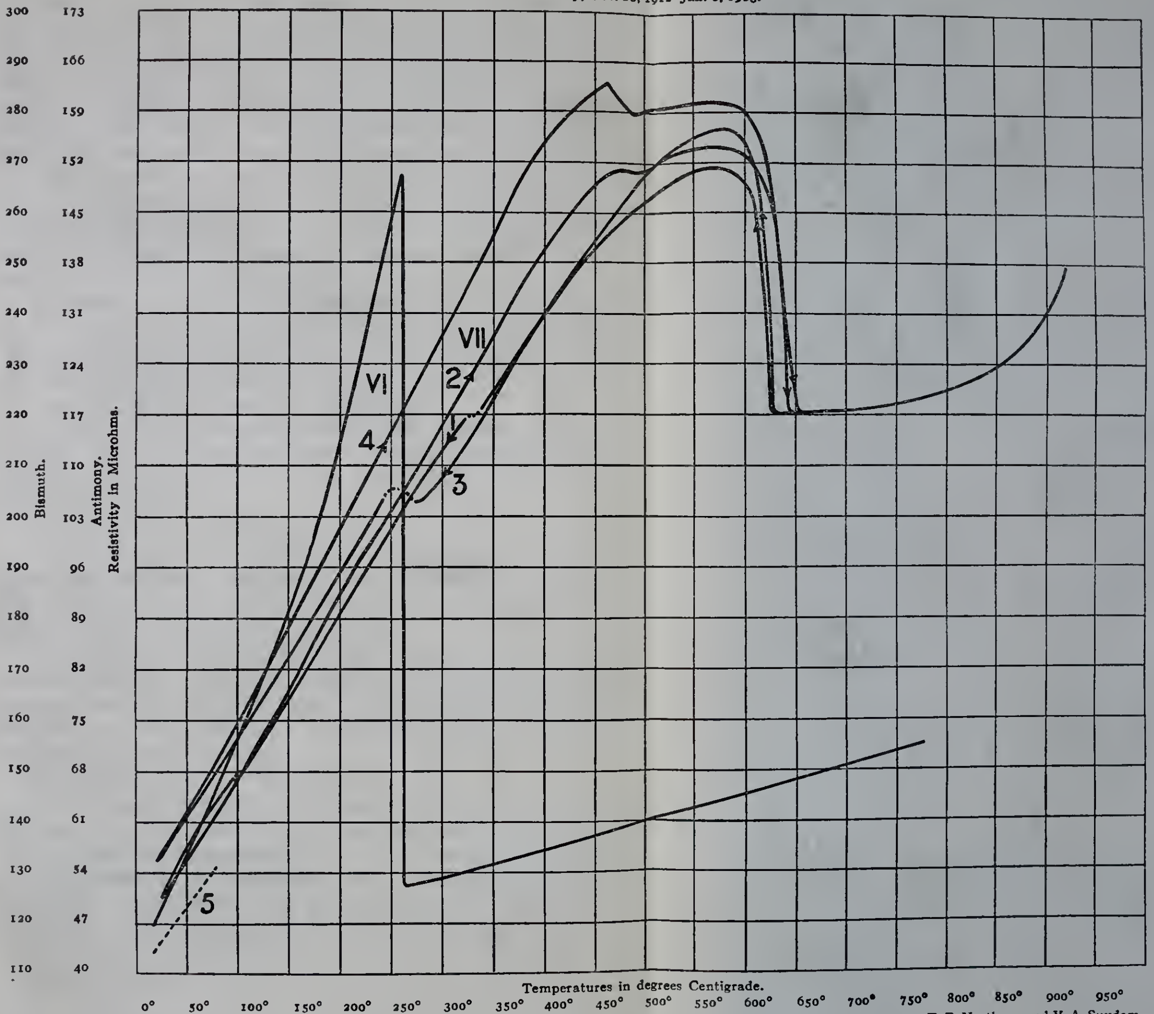
[1] *Metallurgie,* Halle, 7, pp. 730–755, Nov., 1910.

FIG. 2.

VI. Bismuth, Dec. 20–22, 1912.
VII. Antimony, Dec. 28, 1912–Jan. 8, 1913.



Observers :—E. F. Northrup and V. A. Suydam.

is 4 per cent. lower than our value. The conclusion, therefore, might be drawn that zinc contracts 4 per cent. in passing from the liquid to the solid state. It is to be remarked, however, that this contraction may not be a uniform diminution of the cross-section of the conductor throughout its length. If the contraction takes place with the formation of small holes or pits in the metal, then the greater resistivity of the metal when measured in the container over the resistivity of the metal measured out of the container is not a true measure of the percentage shrinkage of the metal in passing from the liquid to the solid state. The manner in which the shrinkage occurred is not known to us in the case of zinc.

The negative temperature coefficient of zinc in the range 427° C. to 750° C. is a prominent characteristic shown in this curve, and we believe that this curve is the first published record of a pure metal which shows a negative temperature coefficient over any considerable range of temperature.

By comparing the resistivity of the zinc just after fusion is complete (37.3 microhms) with the resistivity just before fusion begins (17 microhms—value taken from the dotted line), the ratio 2.194 is obtained.

Curve V (Fig. 1) is for tin.

This metal is seen to have a constant variation in resistivity both in the solid and in the liquid state. The ratio of its resistivity just after fusion (47.4 michroms) to its resistivity just before fusion (22.0 microhms) is 2.154.

Paul Müller has determined [2] the resistivity of tin in its liquid state in the temperature range 232° C. to 1000° C. His value at 700° C. is 59.7 microhms. Our value at the same temperature is 59.88 microhms—a difference of 0.3 of 1 per cent. between his value and ours.

Curve VI (Fig. 2) is for bismuth.

As this metal expands upon cooling from the liquid to the solid state it is not necessary to make any correction for contraction when the metal solidifies, as in the other cases above.

The interesting feature of this curve is that bismuth is seen to decrease in resistivity when it passes from the solid to the liquid state. The decrease in resistivity is exceedingly abrupt.

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[2] *Metallurgie,* ibid.

The resistivity just before fusion is 267 microhms, so far as we have any knowledge, the highest resistivity of any pure metal. The resistivity just after fusion is 127.5 microhms. The ratio of the former to the latter is 2.09.

The curve is slightly convex toward the temperature axis while the metal is in the solid state, and is a straight line while it is in the liquid state.

Curves VII (Fig. 2) are for antimony.

These curves represent four determinations made with the same sample—two made with falling temperature and two with rising temperature. Arrows are marked upon the curves to indicate which determinations were made with rising temperature and which with falling. In runs 1, 2 and 3 the temperature was raised to 750°C., but in the fourth run the temperature was raised to 915° C., when indications were given of the formation of a bubble of vapor—not a bubble of gas, because on lowering the temperature the resistivity returned to the same value (around 800° C.) as was previously observed.

The curves for antimony all come together very exactly when the metal has passed completely into its molten state. This fact, together with the great care exercised throughout the measurement, leads us to believe that the wide departures and the inflexions in the curves where they express the resistivity in the solid state represent true physical phenomena. Antimony crystallizes and probably assumes in the container, above a certain temperature, an amorphous condition. These facts very probably account for the wide variations in the resistivities as observed in the solid state in the different determinations. The resistivity was obtained by measuring a cast rod of the same specimen as that studied in the container. In order to obtain the rod the antimony was melted in a graphite crucible and cast in a graphite mould. The crystalline structure of this sample was observed to be very different from that of a sample taken from the container and which had cooled from the liquid state with extreme slowness. The results of this determination are shown by the dotted line 5, Fig. 2. The value obtained at 20° C. was 43.47 microhms per centimeter-cube. W. Haken's value [3] at 18° C. is 43.48, and estimated for 20° C. is 43.65 microhms.

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[3] *Ann. Physik* (4), 32, 336.

We shall reserve to a later report our further discussion of the peculiarities of this erratic substance. We hope to secure additional infomation which will help to clear up the causes of the irregular behavior of antimony in its solid state.

We give below a short table of some of the values found by us for the resistivities of the above substances at different temperatures:

Cadmium		Lead		Zinc	
Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube
300	16.52	319	50.00	415	17.00
325	33.76	333	95.00	427	37.30
350	33.60	400	98.30	450	37.08
400	33.70	450	100.55	500	36.60
450	33.90	500	102.85	550	36.20
500	34.12	550	105.05	600	35.90
550	34.44	600	107.25	650	35.72
600	34.82	650	109.51	700	35.60
650	35.26	700	111.75	750	35.59
700	35.78	750	114.00	800	35.60
		800	116.20	850	35.74

Tin		Bismuth		Antimony	
Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube
225	22.00	17.5	120.00	627	117.00
235	47.60	100	156.50	650	117.07
300	49.44	150	181.65	700	117.65
350	50.76	200	214.50	750	118.53
400	52.00	259	267.00	800	120.31
450	53.30	263	127.50	850	123.54
500	54.62	300	128.90	900	131.00
550	55.94	350	131.55		
600	57.22	400	134.20		
650	58.58	450	137.00		
700	59.88	500	139.90		
750	61.22	550	142.50		
		600	145.25		
		650	148.00		
		700	150.85		
		750	153.55		

PALMER PHYSICAL LABORATORY,
PRINCETON, N. J., Jan. 17, 1913.

Ductile Tungsten. C. G. FINK. (*Eighth Int. Congr. of Appl. Chem.*, 1912.)—A description of the properties and uses of ductile tungsten. Some of the applications mentioned are the use of tungsten wire gauze for separating solids from acid liquors, etc.; the use of the metal for standard weights, acid-proof dishes and tubes, watch-springs, etc., and in conjunction with molybdenum for thermo-couples, *e.g.*, for measuring high temperatures in the "tungsten-hydrogen furnace." The electromotive force of the couple increases with the temperature up to 540° C. 12½ millivolts, then decreases, and becomes *nil* at about 1300° C.

No Substitute for Tin. ANON. (*Brass World*, viii, 12, 420.)—The present high price of tin reminds us that there is no substitute for this metal in practically all its uses. The manufacture of tin plate takes most of it; the consumption in tin cans for containing food is enormous, and there is no substitute. There is no substitute for tin in bronze and composition castings, and it is indispensable in order to obtain the absolutely necessary casting qualities and hardness. There is an enormous consumption of solder, which cannot be made without tin. There is no substitute for either tin or copper, and it is difficult to see how we could get along without either of them.

Action of Water and Sodium Hydroxide on Cotton Cellulose. M. ROBINOFF. (*Papierfabr.*, x, 968.)—This is a study of the behavior of cotton toward dry heat, water at high temperatures, dilute acids, and dilute and concentrated sodium hydroxide. The chief conclusion is that cellulose which has become modified in the course of industrial chemical treatments possesses totally different properties from normal cellulose. Normal cellulose is extremely resistant, and is only slightly modified when boiled with water under pressure. On the other hand, cellulose which has been subjected to boiling and bleaching processes is very considerably attacked by boiling water under pressure, especially at temperatures above 150° C., and is completely broken down to hydro-cellulose when digested under a pressure of 20 atmospheres. Duration of treatment has no appreciable influence, apparently. Cold and hot (up to 100° C.) dilute sodium hydroxide lyes have no effect on the structure or chemical properties of cellulose, but these lyes have great effect at higher temperatures. A concentration of 4 per cent. sodium hydroxide appears particularly dangerous. Duration of action has little effect. In souring after bleaching, it appears that dilute acids act more energetically on the cellulose than acid of double or quadruple strength. Acetic acid seems to have as much action as hydrochloric acid. Normal Egyptian cotton, after treatment in the heating engine for four hours, showed an increase in hygroscopic moisture, copper value, and hydrolysis value.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

LEGAL SPECIFICATIONS FOR ILLUMINATING GAS.

By E. B. ROSA, Chief Physicist, and R. S. McBRIDE, Assistant Chemist, Bureau of Standards.

The revision of the Bureau of Standards Circular No. 32 on "State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas" was discussed before the American Gas Institute in connection with the presentation of this paper. A consideration of relative merits of candle-power and heating value regulations as the basis of the legal specifications for gas quality indicates the greater advantage of the heating value standard as the principal basis for the regulations; however, it will be best in general to retain a candle-power limit in municipal ordinances for the protection of open-flame burner users. The candle-power limit should be so low as to be less than the value which will ordinarily be met by present-day methods, in order that no undue expense of manufacture will result from its presence in the law. In effect, it will serve only to hold gas manufacture along present methods until it is shown that other methods operate to the advantage of the gas user, and it thus prevents changes in manufacture profitable to the company without a new basis of specification which will ensure that the customer is given some advantage in the change.

A full discussion of the "net" and "total" heating values indicates the significance of each and concludes that either may be used with perfect fairness and without uncertainty. A new method of computing the total heating value by correction for the latent heat of the water vapor carried out of the calorimeter is indicated; this method is recommended for general adoption in official testing where an accuracy of greater than two per cent. is needed.

Some errors in the current method of calculation of candle-power of gas are indicated. These are very large in cities of high altitude. No entirely satisfactory means of eliminating this irregularity is at present available, but further work on this subject is promised by the Bureau, with the idea of gathering such data as will permit a fairer and more satisfactory system of gas candle-power rating.

The use of an open-flame test burner for gas candle-power measurements is again recommended; and a number of the phases of gas quality regulation are briefly discussed.

A SIMPLIFIED FORMULA FOR THE CHANGE IN ORDER OF INTERFERENCE DUE TO CHANGES IN TEMPERATURE AND PRESSURE OF AIR.[1]

By IRWIN G. PRIEST, Assistant Physicist.

THE author developed independently for use at the Bureau of Standards the following correction formula:

$$K = \left(\frac{b_1}{1 + at_1} - \frac{b_2}{1 + at_2}\right) l \left[\frac{\omega - 1}{380\,\lambda}\right]$$

where t_1 = lower temperature Centigrade
t_2 = higher temperature Centigrade
b_1 = pressure in mm. of mercury at temp. t_1
b_2 = pressure in mm. of mercury at temp. t_2
l = distance between mirrors
ω = refractive index at 0°, 760 mm.
a = coef. of expan. of air
λ = wave-length.

He noticed later that the formula published by Pulfrich,[2] viz.:

$$K = l\,(t_2 - t_1)\,\frac{b_1}{760} \cdot \frac{1}{1 + at_1} \cdot \frac{1}{1 + at_2} \left[\frac{2\,(\omega - 1)\,a}{\lambda}\right]$$
$$- \,l\,(b_2 - b_1) \cdot \frac{1}{1 + at_2}\,\frac{2\,(\omega - 1)}{760\,\lambda}$$

could be reduced to this simpler and more convenient form. The derivation of the new formula is given and the two formulas are compared as to convenience in practice.

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[1] To understand this abstract the reader must see first Pulfrich, *Zeit. für Inst. K.* 13, 456.

[2] The sign in Pulfrich's paper is in error if the expression is to give the *correction*, not the *error*.

THE DENSITY AND THERMAL EXPANSION OF ETHYL ALCOHOL AND ITS MIXTURES WITH WATER.[1]

By N. S. OSBORNE, E. C. McKELVY, and H. W. BEARCE.

PART I deals with the preparation of pure ethyl alcohol. Ethyl alcohols from different sources were subjected to purification treatments. The lower boiling impurities were completely removed by heating the alcohol for a considerable time under a reflex condenser, the water of which was held at about 60° C. Dehydration was accomplished by means of lime, aluminum amalgam, and metallic calcium, giving an alcohol of nearly identical physical properties. The first two gave equally good results. The density values obtained with metallic calcium were somewhat higher. The physical properties used as criteria of purity were the density and the critical solution temperature of alcohol-kerosene mixtures (Crismer). These two methods are of approximately equal sensitiveness. An alcohol was obtained which when subjected to an additional dehydration and fractionation gave alcohol of the same density and with no separation into fractions of different densities. Dehydration and subsequent fractionation under reduced pressure gave alcohol of essentially the same density. These results indicate that the alcohol was pure within the limits set by the accuracy of determination of the physical constants used as criteria of purity. Dissolved acetic aldehyde increased the density, while ethyl ether and air decreased it.

The low results obtained for the density of anhydrous ethyl alcohol by Messrs. Squibb could not be obtained by a repetition of their procedure. A repetition of the procedure of Mendeléef gave results closely agreeing with his. Tables are given showing the comparison of results with those of former investigators. The mean density of fifteen of the fractions regarded as the purest was found to be 0.78506, at 25° C.

In Part II is reported the investigation upon the thermal expansion of mixtures of ethyl alcohol and water. Twelve mixtures of alcohol and water were prepared and their densities at 10°, 15°, 20°, 25°, 30°, 35°, and 40° C. determined by the method of hydrostatic weighing. The observations of density for each mixture were reduced by the method of least squares and the coefficients of the assumed equation

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[1] Scientific Paper No. 197, from Bulletin of the Bureau of Standards, vol. 9.

$$D_t = D_{25} + \alpha (t - 25) + \beta (t - 25)^2 + \gamma (t - 25)^3$$

determined. The values of D_{25}, α, β and γ for the twelve mixtures are shown in Table I.

TABLE I.

Per cent. Alcohol by Weight	Density at 25° C.			
	g/ml	$\alpha \times 10^7$	$\beta \times 10^8$	$\gamma \times 10^{10}$
0.000*	0.997077	−2565	−484	+319
4.907	0.988317	−2684	−502	+311
9.984	0.980461	−3119	−484	+258
19.122	0.967648	−4526	−393	+180
22.918	0.962133	−5224	−331	+100
30.086	0.950529	−6431	−226	+ 47
39.988	0.931507	−7488	−145	− 4
49.961	0.909937	−8033	−128	− 24
59.976	0.887051	−8358	−121	− 24
70.012	0.863380	−8581	−117	− 9
80.036	0.839031	−8714	−108	− 69
90.037	0.813516	−8746	− 93	− 51
99.913	0.785337	−8593	− 57	− 62

* Water according to Chappuis.

The values of α, β and γ for each integral per cent. of alcohol between 0 and 100 were then obtained by interpolation.

Part III treats of the density of ethyl alcohol and its mixtures with water. The mean of fifteen determinations of the density at 25° C. of the purest alcohol obtained was found to be 0.78506 gram per millilitre. A series of twenty-five mixtures of known percentages of alcohol and water were prepared as close as possible to integral per cents and their densities at 25° C. determined, partly by the method of hydrostatic weighing and partly by the use of special picnometers; the same constant temperature bath being used in both methods. The densities of the various mixtures, reduced to the nearest integral per cent., are shown in Table II. The values for 90 and 95 per cent. are each the mean results of two mixtures.

TABLE II.

Per cent. Alcohol by Weight	Density (*) at 25°C. g/ml	Per cent. Alcohol by Weight	Density at 25° C.
0	0.997077	55	0.898502
2	0.993359	60	0.886990
5	0.988166	65	0.875269
6	0.986563	70	0.863399
10	0.980434	75	0.851336
15	0.973345	80	0.839114
20	0.966392	85	0.826596
25	0.958946	90	0.813622
30	0.950672	95	0.799912
35	0.941459	98	0.791170
40	0.931483	99	0.788135
45	0.920850	100	0.785058
50	0.909852		

* These density values are for mixtures saturated with air.

Tables I and II permit the calculation of the density of any mixture of ethyl alcohol and water at any temperature between 10° and 40° C. (Circular No. 19, Bureau of Standards).

Part IV describes a second and independent series of mixtures of known percentages of alcohol and water which were prepared and their densities determined at 15° and 25° C., thus furnishing, at the same time, a check on both the density at 25° and the change of density between 15° and 25°.

BUREAU OF STANDARDS.

DURING the fiscal year 1911-12 the activities of the Bureau resulted in a larger number of published papers than heretofore. The results of 35 scientific and technologic investigations were issued. The staff consisted of 192 scientific and other assistants, of whom about 80 were engaged upon special researches and investigations specially authorized by Congress. About 73,196 tests were made in addition to the researches completed and in progress during the year. The inspection work at the factories was developed for both cement and electric lamps, about 2,000,000 barrels of cement being sampled and 1,000,000 electric lamps inspected at the factories. The development of standard specifications for various materials has proceeded steadily in co-operation with the national technical societies and the various departments of the Government. These will go far toward establishing definite standards of quality based upon the measured properties of the materials involved and thus benefit alike the manufacturer and the user of the materials. As heretofore, the demands for special investigations connected with standards, methods of measurement, and the properties of materials are more than can be met with the assistants available. The Bureau has been constantly called upon as referee and consultant by various departments of the Government, and for information and aid by public-service corporations and public-utilities commissions. As far as possible it has responded to these requests.

Antiseptic Tests of Wood-preserving Oils. A. H. DEAN and C. R. DOWNS. (*Eighth Int. Cong. Appl. Chem., Sect. VIa, Orig. Comm.*, xiii, 103.)—From the results of the author's experiments with *Polystictus versicolor,* the commonest of the wood-rotting fungi, it is evident that coal tar creosote is a stronger antiseptic than water-gas tar creosote, and that the latter is distinctly more effective than the liquid oil of the anthracene fraction of coal tar. The greater value of the coal tar oil appears to depend upon the presence of the tar acids, and especially on the tar bases. Water-gas tar creosote was found to be almost identical in antiseptic power with the coal tar oil with its tar acids removed. Alleman has shown that the oils remaining in wood treated with coal tar creosote are almost free from tar acids after a few years of service, and that under conditions allowing evaporation the lighter hydrocarbons are nearly all lost. Loss of antiseptic power from the disappearance of the tar acids cannot take place with water-gas tar oils, since they are free from phenols in the beginning. Since the amount of creosote injected into wood is usually 10 pounds or more per cubic foot, the difference in antiseptic power between coal tar oils and water-gas tar oils does not appear to be of much significance, particularly as the tar acids tend to disappear from the wood treated with coal tar oil. It is considered that water-gas tar creosote has a distinct value for the preservation of wood.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, January 15, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 15, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 10.

The tellers, Messrs. Colvin, Cullen, and Jennings, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers.

The following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Robert S. Perry, E. H. Sanborn, Managers (to serve three years).

The President presented a statement of the work of the Institute during the past year.

Following the meeting of the Institute for the transaction of this business, the Chairman introduced Mr. Elmer A. Sperry, of The Sperry Gyroscope Company, New York City, who presented a communication on the "Applications of the Gyroscope to Marine Purposes."

After a brief reference to the theory of the gyroscope, its applications as a marine compass were discussed at length, and the advantages of the gyrostatic compass over the magnetic compass, particularly for naval purposes, were pointed out. The practical application of the gyroscope to the stabilizing of marine and aërial craft was also fully considered and specific instances described.

The subject was illustrated by numerous lantern slides and working models.

After a brief discussion the thanks of the meeting were extended to the speaker, the subject was referred to the Committee on Science and the Arts for investigation, and the paper was referred to the Committee on Publications.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1912, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To the Members of The Franklin Institute:

The Board of Managers formally present herewith the reports of the standing committees of the past year. These reports have been printed, and copies will be sent to the members. The Board hope that you will learn from these reports that the work of the Institute was pushed with vigor during the year 1912, and is to-day in a condition satisfactory to you.

The Committee on Instruction again report an increase in the enrolment of students and in the number of graduates. The extensive improvements that have been made to the school rooms, rendering them more sanitary, more convenient, and otherwise more attractive with the close attention given to the educational affairs of the Institute by the Committee on Instruction and by the faculty, are being more and more appreciated by young men seeking to better their education through night work.

The report of the Committee on Election and Resignation of Members shows an increase in the number of members elected during the year of over 100 per cent., as compared with the previous year. The Institute is slowly growing in numbers.

The Board call your especial attention to the report of the Committee on Publications, in which you will find a list of men who have consented to act as Associate Editors of the JOURNAL. Each of these men is recognized as an authority, many without a peer, in his particular field of work. It would be difficult to exaggerate the importance to the JOURNAL and to the scientific world of this association. The Year-Book of the Institute for the current year, gotten out by the Committee on Publications, is a valuable document for any one interested in the affairs of the Institute.

The Committee on Sectional Arrangements report as usual a successful year.

The Endowment Committee report that since the opening of the fiscal year the Institute has received an endowment of $50,000 from a friend of the Institute, as a memorial of the late James H. Cresson, a former member. This fund is to be kept intact, and the interest upon it is at the disposal of the managers for use in the work of the Institute. Within the past eighteen months nearly $200,000 have been added to the endowment funds of the Institute, in the care of our Board of Trustees.

The Committee on Library report a large increase in the number of books and pamphlets in the library.

For the first time in many years, we have an important report from the Committee on Museums. We call this to your especial attention, and we hope that many members of the Institute will make it convenient to visit the building, during the daytime, and examine the many beautiful models that the Committee on Museums have recently placed on exhibition. Some of these are exceedingly valuable historically, and each is an example of the finest product of the model maker's skill.

The report of the Committee on Science and the Arts is, as always, interesting, and shows that the work of the committee is well kept up. Medals have been awarded this year to some of the most distinguished scientists of the world, and have been received with expressions of high appreciation.

Your Board have great pleasure in calling your attention to the improvement in the financial condition of the Institute. Although our income from dues and endowment is still less than our expenditures in the prosecution of the Institute's work, the difference is now gradually diminishing from year to year.

The Building Fund still grows slowly, and we cannot venture to prophesy when it will be sufficient to justify us in the purchase of land and the erection of a new building. In the meantime, these old walls, which have echoed in their day the voices of the foremost scientists of the world, and are still, from month to month, sheltering guests who bring to us the best scientific thought of the world, are proving sufficient to our needs, though, through their relatively inaccessible location, somewhat limiting the usefulness of our activities to the citizen and to the State.

Respectfully submitted for the Board of Managers.

WALTON CLARK,
President.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON INSTRUCTION.

To the Board of Managers:

The 88th year of the School of the Institute, and the second year of the Franklin Institute School of Mechanic Arts as reorganized, opened in September, 1911, with an enrolment of 249 students, an increase of 43 over the preceding year.

The faculty of the school for the year 1911–1912 was as follows:

Professor William H. Thorne, Director, in charge of the Department of Drawing.

Professor Clement Remington, in charge of Architectural and Freehand Drawing.

Messrs. A. T. Klein, I. P. Pedrick, and W. W. Twining, Assistants in Mechanical Drawing.

Professor William E. Bullock, Assistant Director, in charge of the Department of Mechanics.

Professor H. P. Tyson, in charge of the Department of Mathematics.

Mr. R. R. Umstead, Instructor in Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

The plan of instruction in the four departments was that adopted at the reorganization of the school two years ago; and the increased registration in all the departments, the improved attendance, and the excellence of the work done appear to justify an adherence to this schedule for the coming year.

The graduating exercises were held in the Hall of the Institute on the evening of April 19, 1912. An address to the graduates was given by Director Morris L. Cooke, of the Department of Public Works, his remarks being on the importance of a technical education from a practical standpoint.

At these exercises thirty-nine students were graduated from the school. Fourteen of these received certificates for Mechanical Drawing, five for Architectural Drawing, four for Freehand Drawing, eight for Mathematics, two for Mechanics, and six for Naval Architecture.

Certificates are in each case awarded on the completion of two years of prescribed work. Their number in Mathematics and Mechanics is usually small in proportion to the registration in any one term on account of the fact that many students enter these departments with the intention of following only partial courses.

Increased facilities have been given the students for studying the historical aspect of engineering by having a large number of the Institute models transferred to the school rooms.

Lectures delivered at stated meetings of the Institute and before the Institute's Sections are open to students of the school. Many of these lectures delivered during the past year were of especial interest to the members of the school, and were well attended by them.

It is hoped that the combined advantages from attending these lectures and from membership in the Alumni Association may increase the interest of the students in the other lines of work carried on by the Institute.

The calendar for 1912–1913 was drawn up on the lines of the two previous issues. A programme of visits to engineering works in and about Philadelphia, arranged for the new season, was included, together with several examples of work done in the school in the preceding year. Announcement was made of a gift by the New York Shipbuilding Company of a valuable set of drawing instruments, to be awarded to the student of greatest merit in the Department of Naval Architecture.

The increased advertising afforded by the new calendar, enlarged to contain more specific information on, and syllabi of, the work, in the various departments, undoubtedly accounts in some measure for the augmented enrolment in the present year. To date a total of 286 students have been registered for the season just commenced, an increase of 37 students over the enrolment of last year. The registration figures for the last three years are included here for comparison:

	Winter Term. 1909–1910.	1910–1911.	1911–1912.	1912–1913.	Spring Term. 1909–1910.	1910–1911.	1911–1912.	1912–1913.
Drawing	98	140	138	158	67	112	116	..
Mathematics	41	37	63	61	18	29	32	..
Mechanics	22	24	28	38	18	21	20	..
Naval Architecture	12	5	20	29	8	5	16	..
	173	206	249	286	111	167	184	..

Respectfully submitted,

For the Committee,
GEORGE A. HOADLEY.

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS.

To the Board of Managers:

During the fiscal year ending September 30, 1912, there were one hundred and ten new members enrolled; resignations were received and accepted from forty-one members, and deaths were recorded of twenty-six members.

The figures for the several classes of membership, with the preceding year for comparison, follow:

Elections:	1910–11.	1911–12.
Resident Members	28	68
Non-Resident Members	15	33
Associate Members	5	7
Honorary Members	0	1
Life Members	4	1
	52	110

Resignations:	1910-11.	1911-12.
Resident Members	12	27
Non-Resident Members	12	13
Associate Members	0	1
	24	41

Deaths:	1910–11.	1911–12.
Resident Members	16	9
Non-Resident Members	5	4
Life Members	9	11
Honorary Members	0	1
Corresponding Members	0	1
	30	26

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE.

Financial Statement, October 1, 1911, to September 30, 1912.

PROPERTY AND FUNDS.

Building and land, 13–17 S. Seventh Street	$60,000.00	
Library	100,000.00	$160,000.00

	Principal.	Unexpended Income.	
Funds held by Board of Trustees	$213,289.10	$96.17	
Funds held by Board of Managers	23,478.50	45.33	
Franklin Institute Building Fund	360,080.22	.....	
Elliott Cresson Medal Fund	1,000.00	2,405.52	
Franklin Fund and Building Committee	4,368.30	.....	
Total funds	$602.216.12	$2,547.02	$604,763.14
Grand total			$764,763.14

LIABILITIES.

Certificates of stock	$30,420.00
Mortgage on Institute Building (held by Trustees as investment for funds)	22,075.00
Bills payable	16,250.00
Accounts payable	4,525.14
Unearned income	943.51
Grand total	$74,213.65

Income and Expenses applicable to Year Ending September 30.

Income.

Dues		$8,777.97
Initiation fees		135.00
General Endowment Fund		6,518.21
Estate of John Turner		136.03
Estate of Robert Wright		1,801.69
Miscellaneous		.29
Membership badges		5.20
Instruction: Drawing	$1,253.50	
Mathematics	471.00	
Mechanics	240.00	
Naval Architecture	270.00	2,234.50
Publications: Subscriptions and sales	$1,800.89	
Advertising	2,945.61	4,746.50
Total		$24,355.39

Expenses.

Building: Wages	$1,019.93	
Repairs and maintenance	318.58	
Heat, light, and power	699.85	
Taxes, water rent, and insurance	809.22	
Miscellaneous supplies and expense	243.59	$3,091.17
Elections and resignations		32.97
Instruction: Drawing	$1,010.50	
Mathematics	237.82	
Mechanics	155.91	
Naval architecture	220.00	
Miscellaneous expense	494.50	2,118.73
Library: Salaries	$3,567.10	
Books and periodicals	1,672.81	
Binding	727.50	
Miscellaneous expense	479.31	6,446.72
Meetings		414.65
Office and General: Salaries	$7,177.12	
Office expense	724.10	
General expense	1,082.03	8,983.25

Publications: Printing	4,863.30	
Reprints	136.00	
Illustrating	390.48	
Miscellaneous expense	478.37	
Year-Book	488.38	6,356.53
Science and Arts		1,156.50
Sections		715.75
Interest and discount		840.38
Model repairs		78.17
Interest paid John T. Kille on donation to General Endowment Fund		200.00
Total		$30,434.82
Net expense		6,079.43

During the fiscal year there has been an increase in funds as follows:

General Endowment Fund	$148,105.21
Elizabeth M. Graff Fund	16.79
Franklin Institute Building Fund	8,651.62
Franklin Fund and Building Committee	85.73

The large increase in the General Endowment Fund was principally caused by the Noblit bequest of $135,822.79, and the Blanchard bequest of $10,000.

The mortgage on the Institute building has been increased by $19,250. Bills payable have been decreased by $12,000.

The excess of expense over income for the year was $6,079.43. This deficit was due to outlays required to maintain the Institute in its present condition of affording satisfactory service to its members and the public.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

(*Abstract.*)

To the Board of Managers:

Two principal features mark the activity of the Institute in the matter of its publications during the past year. The most important of these is the assistance obtained by the Committee on Publications in the editorial management of the JOURNAL, a function which, in the nature of things, could at best be performed but inadequately by the several members of the committee, and which, in point of fact, required the co-operation of specialists in all the various branches of science and technology.

To meet this requirement, the committee, under the guidance of the

Secretary, has organized a body of Associate Editors, the members of which, all of them recognized authorities in their respective fields of work, have graciously consented to collaborate with the Secretary, and, through that officer, with your committee, in the editorial direction of the JOURNAL. The list of our editorial associates is as follows:

Brigadier General James Allen, Chief Signal Officer U. S. Army, War Department, Washington, D. C.

John J. Carty, Chief Engineer, American Telephone and Telegraph Company, New York.

A. S. Cushman, Ph.D., Director, Institute of Industrial Research, Washington, D. C.

Louis Duncan, Ph.D., Consulting Electrical Engineer, New York City.

Harry C. Jones, Ph.D., Professor of Physical Chemistry, Johns Hopkins University, Baltimore, Md.

Harry F. Keller, Ph.D., Professor of Chemistry, Head of Department of Chemistry and Biology, Central High School, Philadelphia.

Alfred Noble, C.E., LL.D., Consulting Civil Engineer, New York City.

L. A. Osborne, M.E., Vice-President, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

Edgar F. Smith, Ph.D., Sc.D., LL.D., Provost, University of Pennsylvania, Philadelphia.

Major George Owen Squier, Ph.D., Military Attaché, American Embassy, London, England.

Charles P. Steinmetz, M.A., Ph.D., Consulting Engineer, General Electric Company; Professor of Electrical Engineering, Union College, Schenectady, N. Y.

S. W. Stratton, D.Eng., Sc.D., Director, Bureau of Standards, Washington, D. C.

Naval Constructor D. W. Taylor, U. S. Navy, Washington, D. C.

S. M. Vauclain, Sc.D., Vice-President, The Baldwin Locomotive Works, Philadelphia.

Edward Weston, Sc.D., LL.D., President, Weston Electric Instrument Company, Newark, N. J.

W. R. Whitney, Ph.D., Director, Research Laboratory, General Electric Company.

R. S. Woodward, C.E., Ph.D., Sc.D., LL.D., President, Carnegie Institution, Washington, D. C.

A. F. Zahm, M.E., Ph.D., Professor of Mechanics, Catholic University of America.

It may well go without saying that the assistance afforded us by these eminent scientists in the editorial management of the JOURNAL has proven to be invaluable in maintaining its contents at the standard of contemporary requirements, and also that it has been effective to the end in view.

In conformity with its recently-adopted regulations, the Committee on Science and the Arts, at its meeting in June last, certified its special appreciation of a number of the more important contributions to the pages of the JOURNAL during the preceding year by awarding to the respective authors the recognition of the Institute in the form of one or another of the several medals at its disposal. No more fitting acknowledgment could well be made.

The second of the two main features of our past year's work is the publication of a Year-Book of the Institute in a form and of a quality commensurate with the dignity of a leading centre of scientific activity. Instead of a pocket edition of this publication, the committee, with the special consent of the Board, has issued this year's edition in full octavo form, which, by dint of painstaking effort on the part of the Secretary and his assistants, presents not only a completely revised directory of the membership of the Institute, but also a compendious statement of its organization and its various activities.

The cost of the Year-Book, which amounts to $488.38, has brought the total cost of our publications during the past year to some $1600 more than the immediate returns derived from them. Leaving out the Year-Book, for which special provision was made by the Board, there appears a debit balance of some $1100 on what is practically the JOURNAL account, an increase of $690 over the like deficit in the preceding year. Of this amount, some $336 is due to a falling off in the returns and the remainder to a higher cost of printing and incidentals.

In this connection, however, the committee takes occasion to point out that of the total amount of $6,300 appropriated for its requirements during the past fiscal year, a balance of $431.85 remained available at its close. This condition is accounted for by an unexpended balance in the appropriations for illustrations, reprints and miscellaneous expense, but has, of course, only a negative bearing on the actual debit balance of the committee's budget.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

To the Board of Managers:

The Committee on Sectional Arrangements takes pleasure in reporting that the year ending September 30, 1912, has been an unusually satisfactory one from the standpoint of the interest displayed in the sectional meetings. It will be noted, from the accompanying description, that the roll of lecturers includes the names of many men of the highest standing in the scientific and professional worlds. This fact, together with the varied nature of the subjects presented and their scientific and practical importance, accounts in great measure, no doubt, for the largely-increased attendance at the meetings. We trust, however, that this increase in attendance also indicates a growing interest in the lectures at the Institute through the efforts of its members to spread its influence.

During the year just passed nineteen meetings have been held by the various sections, as follows:

PHYSICS AND CHEMISTRY SECTION.

Seven Meetings.

October 30, 1911.
Surface Combustion and Its Industrial Applications.
Prof. W. A. Bone.

November 9, 1911.
Some Electro-Chemical Experiments.
Dr. G. H. Meeker.

December 14, 1911.
Recent Developments in the Field of Physical Chemistry.
Prof. Harry C. Jones.

January 4, 1912.
Some Industrial Research Problems of Public Importance.
Mr. H. A. Gardner.

March 28, 1912.
The History, Properties, Preparation and Uses of the Rare Gases.
Dr. R. B. Moore.

April 11, 1912.
Platinum.
Dr. Harry F. Keller.

April 25, 1912.
The Chemical Defences of the Organism Against Disease.
Dr. Wm. J. Gies.

ELECTRICAL SECTION.

Three Meetings.

October 12, 1911.
Electrical Methods of Intercommunication for Military Purposes.
Major Geo. O. Squier.

February 15, 1912.
Alternating Current Development in America.
Mr. Wm. Stanley.

March 7, 1912.
Electrification on Main line Railways.
Mr. W. J. Clark.

PHOTOGRAPHIC SECTION.

Two Meetings.

October 5, 1911.
High Speed Night Photography.
Mr. G. Dietz.

March 8, 1912.
Symphany in Stereoscopic Radiography.
Dr. P. H. Eijkman, Scheveningen, Holland.

MECHANICAL AND ENGINEERING SECTION.

Four Meetings.

February 1, 1912.
Sun Power.
Mr. Frank Shuman.

February 8, 1912.
Improvements of Our Rivers and Harbors.
Prof. Lewis M. Haupt.

February 29, 1912.
Roads and Pavements and Their Materials of Construction.
Mr. Prevost Hubbard.

April 4, 1912.
Electropneumatics as Applied to Train Control.
Mr. Walter V. Turner.

MINING AND METALLURGICAL SECTION.

Two Meetings.

October 26, 1911.
A Practical Application of Fluorescence in Testing Oils for Industrial Purposes.
Prof. A. E. Outerbridge, Jr.

April 19, 1912.
Natural Gas.
Mr. I. N. Knapp.

SECTION OF AËRIAL NAVIGATION AND AËRONAUTICS.

One Meeting.

January 25, 1912.
Aëronautic Laboratories, Their Establishment and Operation.
Dr. A. F. Zahm.

The meeting of the Section of Aërial Navigation and Aëronautics was the inaugural meeting of this Section.

Most of the lectures were illustrated by lantern slides, and at some of them practical demonstrations were given and exhibits shown.

A number of lectures have also provided most excellent material for the JOURNAL.

CHARLES DAY,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON ENDOWMENT.

To the Board of Managers:

Your committee reports that two endowments were received during the fiscal year ending September 30, 1912, covered by this report: one for $133,822.79, which was received from the estate of the late Joseph H. Noblit, of Philadelphia, and the other for $10,000, which was received from the estate of the late Miss Maria Blanchard, also of Philadelphia.

Both of these endowments were mentioned in the last annual report of the President.

Your committee also reports having received, since the opening of the fiscal year, an endowment of $50,000 from a friend of the Institute as a memorial to the late James H. Cresson, formerly a member of The Franklin Institute.

Your committee believes that, if the members of the Board of Managers would bring the question of endowment to the attention of their friends and others who are interested in the Institute or in the mechanic arts, the needs of the Institute would be given greater publicity.

In the future, when the new building is erected, a large endowment will be necessary to carry on the work of the Institute.

Respectfully submitted,

HENRY HOWSON,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON LIBRARY.

(*Abstract.*)

To the President and Members of The Franklin Institute:

The Committee on Library begs to submit the following report on the activities of the Library during the twelve months ending September 30, 1912:

The additions made to the Library during this period are as follows:

Source.	Bd. Vols.	Unb. Vols.	Pphs.	Maps.	Drawings.	Photos.
Gift	293	487	696		1	24
Exchange account	21	12	6			
Journal	35	24	108	1		
Binding: Institute Appropriation	382					
Chemical Periodicals Binding Fund	26					
Moore Fund	2					
Morris Fund	158					
Institute Appropriation	86	12	3	1		
Lea Fund	128	15	1			
Memorial Library Fund		2				
Moore Fund	338	51				
Morris Fund	40	7				
Potts Fund	8	3				
	1,517	613	814	2	1	24

Total additions for the year, 2,971, being an increase of 871 over the previous year.

Gifts of books, pamphlets, and periodicals in large quantities or of special value were received as follows:

Mr. Hugo Bilgram, copies of technical magazines and society publications.

Mr. Max Freimark, volumes and pamphlets on engineering subjects.

Mr. F. Lynwood Garrison, copies of technical magazines.

Dr. Carl Hering, bound volumes and pamphlets on electrical subjects, and a set of the reports of the juries of the Paris Exposition of 1900.

Dr. Samuel C. Hooker, volumes, pamphlets, and numbers of magazines on chemistry and related subjects.

Mr. Henry Howson, copies of technical magazines.

Robert D. Jenks, Esq., bound volumes and numerous pamphlet reports of railroad companies and State railroad commissions.

Mr. S. Howard Rippey, copies of technical magazines.

Mr. Henry Steck, books on gas manufacture.

Dr. W. H. Trueman, copies of technical magazines.

Messrs. Cope & Stewardson, copies of recent issues of architectural publications.

Crocker-Wheeler Company, Philadelphia, copies of trade papers and engineering periodicals.

The Engineers' Club of Philadelphia, copies of engineering publications for the year 1911.

The Geographical Society of Philadelphia, copies of recent geographical and scientific publications and society transactions.

Messrs. Harris & Richards, volumes, pamphlets, and magazines on architecture and engineering.

The Pennsylvania Railroad Company, pamphlet reports of its leased lines.

U. S. Bureau of the Census, volumes of reports.

The committee is indebted to Mr. Joseph A. Arnold, Editor and Chief, Division of Publications, Department of Agriculture, for copies of the various publications of the department.

THE CONTENTS OF THE LIBRARY.

After transferring the mechanical pamphlets to the bound volumes and deducting the books withdrawn, the Library contains:

Volumes, bound and unbound	62,523
Pamphlets	47,045
Maps and charts	2,271
Photographs	1,336
Newspaper clippings	40,000
Manuscripts	34

BINDING.

Seven-hundred and thirty volumes were bound, 4 volumes were rebound, and 3 were repaired, an increase of 396 over the number of books bound during the preceding year. This increase must be credited to the Morris and Chemical Periodicals Binding Funds. The enormous number of pamphlets on mechanics have thus been made available for reference.

EVENING ATTENDANCE.

The Library was open on forty-two evenings during the year until 10 o'clock.

NOTES.

The additions to the Library during the past year have been greater than in any year since 1900.

This is due to the larger number of purchases and to the results of the more systematic attempts at procuring documents distributed without cost.

During the year two Library Bulletins were issued, the first giving the additions to the Library in the various departments during a period of about two years, and the second a list of the periodicals on file in the Library. These pamphlets will serve to make known to members and others the material contained in the Library, and it is hoped that it will be possible to issue further bulletins of this character in the future.

As pointed out in the report for the preceding year, special funds are urgently needed for the binding of the great mass of books, periodicals, and pamphlets that has accumulated. It seems especially desirable that pamphlets on electrical and chemical subjects should be classified, bound, and catalogued in the same way as the Morris Fund provides for those on mechanics.

Respectfully submitted,

Harry F. Keller,
Chairman.

Philadelphia, January 8, 1913.

REPORT OF THE COMMITTEE ON MUSEUMS.

(*Abstract.*)

To the President and Members of The Franklin Institute:

The Committee on Museums begs to report as follows:

The Franklin Institute possesses a large collection of models of great interest as well as of historical value. For years past many of these have been stored away out of sight in the cellar and elsewhere, covered with dust and the metal portions coated with rust. Through the liberal donations of a few members and the voluntary labors of Mr. Henry F. Colvin, the herculean task of collecting, cleaning, repairing, and classifying, so far as possible, this unique collection of models has been practically completed during the year, and a catalogue containing nearly three hundred separate entries (some covering numerous items) has been prepared by Mr. Bullock, Assistant to the Secretary. The Committee on Museums, having inspected the collection in its resuscitated condition, regard it as an exceedingly valuable asset, and desire to accord to the Secretary, Dr. R. B. Owens, the full credit due to him for having originated and carried to a successful conclusion this important and tedious work.

It is suggested that the catalogue of these models be printed in the Year-Book for 1913.

A brief reference to a few of these models and pieces of apparatus of historical interest will suffice to indicate the priceless value of the collection.

A very complete set of models of water-wheels made for the committee appointed by the Institute to investigate the efficiency of moving water as a motive power and used in conducting its water-wheel experiments. (Report of 1829.)

Original testing machine made for the committee appointed to investigate the strength of materials. This committee devised apparatus of various forms for the testing of metals, steam boilers, building materials, etc., 1832.

Model of canal boat with screw-propellers; also models of ice-boats and boats with feathering paddle-wheel blades.

Models of earliest forms of lattice girder bridges.

Sectional model of early beam engine with Watt parallel motion and condenser.

Model of locomotive engine, by George Stevenson, 1816.

Sectional model of side-lever engine.

Working models of early forms of stationary engines and locomotives.

Models by Eastwick, Harrison, Baldwin, and other inventors, of crank motions and various other portions of engines, such as cylinders, etc.

Model of Herman's mechanism for converting rectilinear into rotary motion.

Beam engine, by Henry Cartwright, model 1842.

Model of first World's Fair premium harrow.

Model of Bain's printing telegraph, 1844.

Various models and working apparatus of Morse and other inventors in the early history of telegraphy.

Model of Oliver Evans's "Oructor Amphibolis."

Original Yale lock, 1855.

Benjamin Franklin's original electrical machine and various other apparatus used by him.

In conclusion, it may be stated that all of the working models have been taken apart, cleaned, repaired by skilled mechanics, and all have been operated.

Some of these models are displayed in the Library and lecture-room; many others line the walls of the class-rooms, where they are at all times available for educational purposes.

Respectfully submitted,

A. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON MEETINGS.

To the President and Members of The Franklin Institute:

During the year ending September 30, 1912, nine stated meetings of the Institute were held under arrangements made by the Committee on Meetings, with the co-operation of the Secretary's office. At these the following subjects were presented:

September 20, 1911: Modern Uses and Applications of Radium. Dr. Hugo Lieber.

October 18, 1911: The Practical Application of Scientific Management to Railway Operation. Mr. Wilson E. Symons.

November 15, 1911: The Obstacles to the Progress of Meteorology. Prof. Cleveland Abbe.

December 20, 1911: Daylight. Dr. Edward L. Nichols.

January 17, 1912: Research Laboratory Notes. Dr. W. R. Whitney.

February 21, 1912: Recent Advances in the Art of Battleship Design. Naval Constructor D. W. Taylor, U. S. N.

March 20, 1912: How the Chemist Uses Electricity. Dr. Edgar F. Smith.

April 17, 1912: Recent Development of the Locomotive. Mr. George R. Henderson.

May 15, 1912: Fundamental Chemical Constants. Dr. E. W. Morley

Recent Developments in the Electrical Art. Prof. Elihu Thomson.

Metrology in Relation to Industrial Progress. Dr. S. W. Stratton.

The May meeting was made the occasion of the presentation of Elliott Cresson Medals to Dr. Alexander Graham Bell, Dr. Edward Williams Morley, Prof. Elihu Thomson, and Dr. S. W. Stratton, the last three being the speakers of that evening. The presentations were made on behalf of the Institute by Vice-President James Mapes Dodge, in the absence of the President, Dr. Walton Clark.

At this meeting, also, an amendment to the By-Laws, providing for the discontinuance of the June and September Stated Meetings, was considered and adopted in its final form.

Throughout the year the meetings were exceedingly well attended. The papers presented have practically all appeared in the Institute's JOURNAL.

Respectfully submitted,

JAMES S. ROGERS,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

To the President and Members of The Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following account of its operation for the year ending September 30, 1912:

During the year there were held eleven Stated Meetings of the General Committee and twenty-three meetings of Sub-committees on Investigation.

There were eighteen cases pending before the committee in September, 1911, and, during the twelve months following, ten applications for investigation were accepted.

Twenty-four cases were closed during the year, leaving four cases pending, September 30, 1912.

In three of the cases considered, the award of the Elliott Cresson Medal was recommended and made. In two cases the award of the Edward Longstreth Medal of Merit was recommended and made. In four cases the award of the John Scott Legacy Medal and Premium was recommended; in two of these cases the John Scott Award was made by the City of Philadelphia; one case is now pending before the Philadelphia Board of City Trusts, and one recommendation is being advertised in the JOURNAL. Thirteen reports were made advisory and two cases were dismissed.

On the recommendation of the Special Committee on the awarding of the Elliott Cresson Medal in recognition of leading and directive work in science and the arts, nine awards were made.

On the recommendation of the Sub-committee on Literature, five Edward Longstreth Medals and one Howard N. Potts Medal for papers published in the JOURNAL were awarded.

A detailed list of the above awards is appended hereto.

No amendments to the Regulations of the Committee were considered.

The Chairman desires to express his sincere appreciation of the active and efficient co-operation of his fellow-members of the committee.

Respectfully submitted,

WILFRED LEWIS,
Chairman.

PHILADELPHIA, January 8, 1913.

APPENDIX.

Details of Awards.

THE ELLIOTT CRESSON MEDAL.

Johann Friedrich Adolph Von Baeyer, Ph.D., F.M.R.S., of Munich, Germany, in recognition of the many important results of his extended researches in organic chemistry and of his discovery of synthetic processes of great industrial value.

Alexander Graham Bell, Sc.D., Ph.D., LL.D., of Washington, D. C., in recognition of the value of his solution of the problem of the electrical transmission of articulate speech.

Sir William Crookes, D.Sc., LL.D., F.R.S., O.M., of London, Eng., in recognition of his important discoveries in inorganic and analytical chemistry and of his pioneer work on the discharge of electricity through gases.

Gray National Telautograph Company, of New York, N. Y., for their Telautograph.

Albert A. Michelson, Sc.D., Ph.D., LL.D., of Chicago, Ill., in recognition of his original and fruitful investigations in the field of physical optics.

Edward Williams Morley, Sc.D., Ph.D., LL.D., of West Hartford, Conn., in recognition of his important contributions to chemical science, and particularly of his accurate determinations of fundamental magnitudes.

Alfred Noble, C.E., LL.D., of New York, in recognition of his distinguished achievement in the field of civil engineering.

Sir Henry Enfield Roscoe, Ph.D., LL.D., D.C.L., F.R.S., of London, England, in recognition of his extended and important researches in the domains of inorganic, physical, and industrial chemistry.

Major George Owen Squier, Ph.D., of Washington, D. C., for his inventions in Multiplex Telephony.

Samuel Wesley Stratton, D.Eng., Sc.D., of Washington, D. C., in recognition of his distinguished and directive work in physical science and metrology, and its application in the arts and industries.

Elihu Thomson, Sc.D., Ph.D., of Swampscott, Mass., in recognition of his leading and distinguished work in the industrial applications of electricity.

Walter V. Turner, of Wilmerding, Pa., for his Air Brake Inventions and Developments.

THE HOWARD N. POTTS MEDAL.

T. Lyttleton Lyon, Ph.D., and James A. Bizzell, Ph.D., for their paper on "The Relation of Certain Non-Leguminous Plants to the Nitrate Content of Soils" in the JOURNAL.

THE EDWARD LONGSTRETH MEDAL.

Professor Charles Baskerville, Ph.D., for his paper on "The Chemistry of Anæsthetics" in the JOURNAL.

Edwin M. Chance, for his paper on "The Examination and Physiological Action of Pathogenic Mine Atmospheres, with Considerations Governing the Use of Breathing Apparatus," in the JOURNAL.

Julian H. Granbery, for his Stadia Rod.

John Prue Karns, for his Tunnelling Machine.

Professor Edwin F. Northrup, Ph.D., for his paper on "An Experimental Study of Vortex Motions in Liquids" in the JOURNAL.

Oswald Schreiner, Ph.D., and Elbert C. Lathrop, A.B., for their paper on "The Distribution of Organic Constituents in Soils" in the JOURNAL.

Professor Carl C. Thomas, M.E., for his paper on "The Measurement of Gases" in the JOURNAL.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Awarded by the City of Philadelphia on the recommendation of The Franklin Institute.

Sherard Cowper-Coles, of London, England, for his Process of Depositing Metals on Metallic Surfaces and the Product Thereof.

Louis W. Downes, of Providence, R. I., for his Process of and Machinery for Insulating Wire with Asbestos.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 8, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 8, 1913.

MR. GEO. R. HENDERSON *in the Chair.*

The following was accepted for examination:

No. 2523.—Ellis Adding Typewriter.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Aërial Navigation and Aëronautics.—A meeting of the section was held on Thursday evening, January 23, 1913, at 8 o'clock, in the Hall of the Institute. The meeting was called to order by Dr. Stradling, who, with a few preliminary remarks, introduced Dr. W. J. Humphreys, Director of the Mount Weather Observatory, U. S. Weather Bureau, and Professor of Meteorological Physics at the George Washington University.

Dr. Humphreys delivered an illustrated lecture on "Physics of the Atmosphere and Aviation."

He spoke of the means of exploring the atmosphere from mountains by means of kites and sounding balloons containing instruments, and, higher, by taking observations of shooting stars, auroral arcs, etc.

He considered the temperature and composition of the air at different levels, illustrating his remarks with interesting diagrams. The discovery of the isothermal—one of the most important discoveries of modern meteorology—and its explanation were described by him in detail.

By means of maps he explained the horizontal movement of the earth's atmosphere, directing attention especially to the "ocean highs."

He discussed wind structure, general circulation of air, and other subjects of vital interest to aëronauts. He also spoke of Simpson's modern theory of the electrical discharge in thunder-storms, giving a lucid description of this subject.

Throughout the lecture Dr. Humphreys held the close interest of his audience, and at the close of his remarks the thanks of the meeting were extended him.

Adjourned.

W. E. Bullock,
Acting Secretary.

Electrical Section.—A joint meeting of the section, and of the Philadelphia Section of the American Institute of Electrical Engineers, was held in the Hall of the Institute on Thursday evening, January 9, 1913, at 8 o'clock, Mr. W. C. L. Eglin and Mr. H. A. Hornor presiding jointly.

With a few introductory remarks Mr. Eglin introduced Mr. W. L. R. Emmet, Consulting Engineer and Engineer of Lighting Department, General Electric Company, Schenectady, N. Y., who spoke on "The Electric Propulsion of Ships."

Mr. Emmet gave some figures on the horsepower capacity of steam turbines now driving ships. He spoke of how these were for the most part applied to the fastest ships only. After mentioning work that had been done on gearing for speed reduction, he outlined the advantages of electricity for the same purpose.

He then showed lantern slides to illustrate his remarks. These slides included details of the electrical equipment (designed by him) on the U. S. collier *Jupiter.*

In the discussion which followed, Mr. Hornor, Mr. E. H. Rigg, and Mr. Bernard took part.

The thanks of the meeting were extended to the speaker.

Adjourned.

W. E. Bullock,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated meeting of the Board of Managers, February 12, 1913.*)

RESIDENT.

MR. ALBERT B. BEADLE, 1328 Chestnut Street, Philadelphia, Pa.
MR. G. W. CURRAN, United Gas Improvement Company, Philadelphia, Pa.
MR. ERNEST HANDFIELD RIGG, 25 High Street, Woodbury, N. J.
MR. FRANK SILLIMAN, JR., 5987 Woodbine Avenue, Overbrook, Pa.

NON-RESIDENT.

DR. L. H. BAEKELAND, "Snug Rock," Harmony Park, Yonkers-on-Hudson, N. Y.
MR. C. A. COFFIN, General Electric Company, 30 Church Street, New York, N. Y.
MR. EDWIN P. GOTWALS, Lansdale, Pa.
MR. S. L. HAYES, 100 North Second Street, Millville, N. J.
PROF. JEFFERSON E. KERSHNER, Franklin and Marshall College, Lancaster, Pa.
MR. WILLIAM STANLEY, Great Barrington, Mass.

Changes of Address.

PROF. JEREMIAH D. BALTIMORE, Armstrong Technical High School, P Street, between First and Second Streets, N. W., Washington, D. C.
MR. GEORGE A. GRAVEMEYER, 122 South Thirteenth Street, Philadelphia, Pa.
DR. SAMUEL C. HOOKER, 82 Remsen Street, Brooklyn, N. Y.
MR. F. P. HOWE, Johnson City, Tenn.
MR. ERNEST JOHANSEN, 2022 Fairmount Avenue, Philadelphia, Pa.
DR. HARRY F. KELLER, 2313 Green Street, Philadelphia, Pa.
MR. TINIUS OLSEN, care of Rector Bertelsen, Roeskilde, Denmark.
MR. C. E. POSTLETHWAITE, P. O. Box 53, Pittsburgh, Pa.
MR. C. E. SARGENT, 2226 North Meridian Street, Indianapolis, Ind.
MR. C. C. TUTWILER, 1630 Real Estate Trust Building, Philadelphia, Pa.
E. D. WILLIAMS, ESQ., 309 South Fifteenth Street, Philadelphia, Pa.

NECROLOGY.

Sir John G. N. Alleyne, Chevin, Belper, England.

A. M. Schreuder was born in 1874. He was graduated from Cornell University as mechanical engineer in 1896. After leaving college, he was employed for some years by the Geo. M. Newhall Engineering Company, of Philadelphia. He then took up a position with the Tabor Manufacturing Company, also of Philadelphia. Early in 1908 Mr. Schreuder entered the employ of The Philadelphia Textile Machinery Company, first devoting his energies to drawing-office work and advancing in a short time to the post of superintendent of the plant, having charge of both the Engineering Department and the shop management.

He died in Philadelphia on January 1, 1913.

LIBRARY NOTES.

Purchases.

APPELL, P.—Traité de mécanique rationnelle, vols. 1–3. 1909, 1911.
BAEYER, ADOLF VON.—Gesammelte Werke. 2 vols. 1905.
DALTON, J., and others.—The Expansion of Gases by Heat. [*c*1902.]
DROEGE, J. A.—Freight Terminals and Trains. 1912.
FARADAY, M.—The Discovery of Induced Electric Currents. [*c*1900.]
FARADAY, M., and others.—The Effects of a Magnetic Field on Radiation. [*c*1900.]
FARADAY, M., and others.—The Fundamental Laws of Electrolytic Conduction. [*c*1899.]
FRIEND, J. N.—The Corrosion of Iron and Steel. 1911.
GILBRETH, F. B.—Primer of Scientific Management. 1912.
GRANT, J.—The Chemistry of Breadmaking. 1912.
HARING, A.—Engineering Law, vol. i. 1910.
HENRY, J.—The Discovery of Induced Electric Currents. [*c*1900.]
HUYGENS, C.—Oeuvres completes, vols. i–xii. 1888–1910.
HUYGENS, C., and others.—The Wave Theory of Light. [*c*1900.]
KAYE, G. N. C., and T. H. LABY.—Tables of Physical and Chemical Constants. 1911.
KNESER, A.—Die Integralgleichungen und ihre Anwendungen in der mathematischen Physik. 1911.
MULLIKEN, S. P.—A Method for the Identification of Pure Organic Compounds, vols. i, iii. 1911.
NEWTON, I., and others.—The Laws of Gravitation. [*c*1900.]
PASTEUR, L., and others.—The Foundations of Stereochemistry. [*c*1901.]
PREVOST, P., and others.—The Laws of Radiation and Absorption. [*c*1901.]
SCHIDROWITZ, P.—Rubber. [1911.]
SENARMONT, H. DE, and others.—Oeuvres completes D'Augustin Fresnel, vols. i–iii. 1866–1870.
TRABERT, W.—Lehrbuch der kosmischen Physik. 1911.
WALKER, S. F.—Cold Storage, Heating and Ventilating on Board Ship. 1911.
WOODALL, H., and B. R. PARKINSON.—Distribution by Steel. 1911.
ZENKER, W.—Lehrbuch der Photochromie. 1900.
ZSIGMONDY, R.—Kolloidchemie. 1912.

Gifts.

West Virginia, Annual Report of the Department of Mines, 1911. Charleston, no date. (From Chief of the Department.)

Wisconsin Geological and Natural History Survey, "Sandstones of the Wisconsin Coast of Lake Superior." Madison, 1912. (From the Survey.)

Illinois Railroad and Warehouse Commission, Annual Reports, 1872, 1899-1904, 1906, 1910, 1911. Special Report, 1902–1906. Springfield, no date. (From the Commission.)

Southern Pacific Railroad Company, 19th–25th, 27th Annual Reports. New York, no date. (From the Company.)

American Society of Civil Engineers, Transactions, vol. 75, 1912. New York, 1912. (From the Society.)

Institution of Civil Engineers, Minutes and Proceedings, vol. 189. London, 1912. (From the Institution.)

Philadelphia, Academy of Natural Sciences, Journal, vol. 15. Philadelphia, 1912. (From the Academy.)

Manchester Steam-users' Association, Annual Report of the Boiler Explosion Act, 1882. Manchester, England, 1910-11. (From the Association.)

Mining Society of Nova Scotia, Journal, vol. 17, 1912–13. Halifax, 1912. (From the Society.)

Philadelphia, Bureau of Surveys, Annual Report, 1911. Philadelphia, 1912. (From the Bureau.)

Kentucky, Report of the Railroad Commission, 1904. Louisville, 1905. (From the Commission.)

Buchanan, N. Y., Experimental Researches on the Specific Gravity and the Displacement of Some Saline Solutions. London, 1912. (From the Author.)

Maine, Annual Report of the Railroad Commission for 1872, 1889, 1891, 1893, 1895, 1896, 1897, 1898, 1899, 1901, 1903, 1904, and 1905. Augusta, no date. (From the Commission.)

Louisiana, 1st, 2nd, 3rd, 4th, 12th, and 13th Annual Reports of the Railroad Commission. Baton Rouge, no date. (From the Commission.)

Hannover, Königliche technische Hochschule, Program, 1912–1913. Hannover, 1912. (From the School.)

Iowa, Annual Report of the Railroad Commissioners for the years 1899, 1901–1908. Des Moines, no date. (From the Commission.)

Kentucky, 31st and 32nd Annual Reports of the Railroad Commission, 1910–11. Frankfort, no date. (From the Commission.)

Florida, Fifteenth Annual Report of the Railroad Commission, 1912. Tallahassee, 1912. (From the Commission.)

Case School of Applied Science, Catalogue 1912–13. Cleveland, 1912. (From the School.)

Wesleyan University, Bulletin, vol. 6, No. 4, January, 1913. Middletown, Conn., 1913. (From the University.)

National Association of Cotton Manufacturers, Transactions, No. 91. Boston, 1912. (From the Association.)

New Zealand, Papers and Reports Relating to Minerals and Mining, 1912. Wellington, 1912. (From the Department of Mines.)

U. S. Army, Index Catalogue of the Library of the Surgeon-General's Office, Second Series, vol. 17. Washington, 1912. (From the Library.)

Great Britain, Board of Trade (Labor Department) Report on Strikes and Lock-outs, 1911. London, 1912. (From the Department.)

Ontario Department of Agriculture, Report of the Women's Institutes, 1912, Part 1. Toronto, 1912. (From the Department.)

Cuba, Instituto De 2ª Ensenanza, Memoria Anual 1909 á 1910. De La Habana, 1912. (From the Instituto.)

Canada, Minister of Public Works, Report 1912, vol. 1. Ottawa, 1912. (From the Minister.)

Vermont Historical Society, Proceedings 1909–10. Montpelier, no date. (From the Society.)

Massachusetts, State Board of Health, Annual Report 1911. Boston, 1912. (From the Board.)

"George von Reichenbach," by Walther von Dyck. München, 1912. (From the German Museum of Munich.)

Institution of Naval Architects, Transactions, vol. 54. London, 1912. (From the Institution.)

Institution of Naval Architects, Index to Transactions, vols, 47 to 54. London, 1912. (From the Institution.)

PUBLICATIONS RECEIVED.

Fatty Foods, their Practical Examination. A handy book for the use of analytical and technical chemists, by E. Richards Bolton, F.C.S., and Cecil Revis. 371 pages, illustrations, plates, 12mo. Philadelphia, P. Blakiston's Son & Co., 1913. Price, in cloth, $3.50.

Methods of Measuring Electrical Resistance, by Edwin F. Northrup, Ph.D. 389 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1912. Price, in cloth, $4.00.

Michigan State Board of Health, Thirty-ninth annual report of the Secretary for the fiscal year ending June 30, 1911. 118 pages, 8vo. Lansing, State Printers, 1912.

North Carolina Geological and Economic Survey: Economic Paper, No. 29, Report of the Fisheries Convention held at Newbern, N. C., December 13, 1911. Compiled by Joseph Hyde Pratt, State Geologist. 302 pages, 8vo. Economic Paper, No. 30, Proceedings of the Annual Convention of the North Carolina Good Roads Association, held at Charlotte, N. C., August 1 and 2, 1912, in co-operation with the North Carolina Geological and Economic Survey. Compiled by Joseph Hyde Pratt, State Geologist, and Miss H. M. Berry, Secretary. 110 pages, 8vo. Raleigh, State Printers, 1912.

Canada Department of Mines, Mines Branch: A General Summary of the Mineral Production of Canada during the Calendar Year 1911. John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 38 pages, 8vo. The Production of Coal and Coke in Canada during the Calendar Year 1911. John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 35 pages, 8vo. Ottawa, Government Printing Bureau, 1912.

Philippine Islands, Bureau of Science, The Mineral Resources of the

Philippine Islands for the year 1911. Issued by the Division of Mines, Bureau of Science, Warren D. Smith, Chief. 99 pages, illustrations, maps, plates, 4to. Manila, Bureau of Printing, 1912.

U. S. Bureau of Standards, Circular No. 39, Specifications for and Measurement of Standard Sieves. 14 pages, 8vo. Washington, Government Printing Office, 1912.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin, Jahresbericht 1911. Aufgaben, Gliederung des Betriebes und Grundsätze für die Geschäftsführung. 2 pamphlets, 4to. Berlin, Julius Springer, 1912.

Pennsylvania Chestnut Tree Blight Commission, Bulletin No. 2, Treatment of Ornamental Chestnut Trees Affected with the Blight Disease. 7 pages, illustrations, 8vo. Harrisburg, State Printer, 1912.

U. S. Department of Agriculture, Forest Service: Bulletin 104, Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram, by Harry D. Tiemann, in charge Timber Physics. 19 pages, tables, 8vo. Circular 205, Forest Fire Protection under the Weeks Law in Co-operation with States, by J. Girvin Peters, Chief of States Co-operation. 15 pages, maps, 8vo. Report of the Forester for 1912, by Henry S. Graves. (From annual reports of the Department of Agriculture.) 95 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines: Miners' Circular 10, Mine Fires and how to Fight Them, by James W. Paul. 14 pages, 8vo. Technical Paper 29, Training with Mine-Rescue Breathing Apparatus, by James W. Paul. 16 pages, 8vo. Washington, Government Printing Office, 1912.

University of Colorado Bulletin, Municipal Water Supplies of Colorado, by Clement C. Williams, C. E., Assistant Professor of Civil Engineering. 56 pages, illustrations, map, 8vo. Boulder, Col., University, 1912.

Royal Institution of Great Britain, Weekly evening meeting, Friday, May 17, 1912, High Frequency Currents, by W. Duddell, Esq. 23 pages, illustrations, 8vo. Friday, May 31, 1912, Icebergs and their Location in Navigation, by Professor Howard T. Barnes. 20 pages, illustrations, 8vo. London, Institution.

U. S. Geological Survey, Chart showing mineral products of the United States, calendar years 1902 to 1911, size 24 x 32 inches. Washington, 1912.

U. S. Commissioner of Lighthouses, Annual report for the fiscal year ended June 30, 1912. 108 pages, 8vo. Washington, Government Printing Office, 1913.

BOOK NOTICES.

The Metallography of Iron and Steel. By Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University. One volume quarto, edition 1, University Press, Cambridge, Mass., 1912, cloth, $6.

This really splendid work gives to the metallurgists the "last word" regarding a comparatively new science—that of Micro-Metallography—the birth of which was very nearly contemporaneous with the coming of the twentieth century.

Twenty years ago a few pioneers had already paved the way for enthusiastic followers, like Professor Sauveur, by their original investigations with the microscope, assisted by photography, into the molecular structure of metals, revealing complicated combinations hitherto unknown. Chemical analysis had long before that time made us acquainted with the component elements of alloys; we had attained the *ultima thule* of knowledge of the chemical composition of metals and alloys, but until the powerful eye of the microscope was trained upon the polished and etched surfaces of such metals we were unable to explain the vast differences in physical properties of pure metals and their alloys caused by differences of heat treatment, or by minute variations in compositions too small for detection by ordinary chemical analysis, or by still other more or less mysterious causes.

For several years the whole subject of micro-metallography was regarded by practical men as an interesting one solely from an academic or theoretical point of view, but, gradually at first, then more and more rapidly, came a realization of the immense importance of micro-metallography in industrial establishments engaged in manufacturing and fashioning metals into various useful forms.

Professor Sauveur was a pioneer in this latter development, and the writer regards the now somewhat scarce volumes of "The Iron and Steel Metallurgist and Metallographist," edited by Professor Sauveur for several years, more than a decade ago, as a remarkable monument to his energy and foresight, which has now found its full fruition in the classic book under review, which will doubtless be considered by experts as entitled to this encomium.

The book is divided into twenty-four chapters, called "Lessons." Each one is a complete text-book in itself upon a special branch of the main subject, copiously illustrated with diagrams and photo-micrographs. There is an interesting "Introduction" clearly showing the industrial importance of Metallography; also a full description of apparatus for the metallographic laboratory, and various appendices, together with complete "Index" and "Table of Contents."

With such a wealth of subjects to choose from it is somewhat difficult to specify any one as having particular importance, but attention may be called to the very clear exposition of the meaning of "The Phase Rule" not always understood.

The following is a list of the "lessons" or chapters:

(1) Pure Metals.
(2) Pure Iron.
(3) Wrought Iron.
(4) Low Carbon Steel.
(5) Medium High and High Carbon Steel.
(6) Impurities in Steel.
(7) Thermal Critical Points of Iron and Steel. (Occurrence.)
(8) Thermal Critical Points of Iron and Steel. (Causes.)
(9) Thermal Critical Points of Iron and Steel. (Effects.)
(10) Cast Steel.
(11) Mechanical Treatment of Steel.

(12) Annealing of Steel.
(13) Hardening of Steel.
(14) Tempering of Hardened Steel.
(15) Theories of Hardening of Steel.
(16) Cementation and Case Hardening of Steel.
(17) Special Steels. (General Considerations.)
(18) Special Steels. (Constitution, Properties, and Treatment and Uses of Most Important Types.)
(19) Cast Iron.
(20) Impurities in Cast Iron.
(21) Malleable Cast Iron.
(22) Constitution of Metallic Alloys.
(23) Equilibrium Diagram of Iron-Carbon Alloys.
(24) The Phase Rule.
Appendix 1, Manipulations and Apparatus.
Appendix 2, Nomenclature of the Microscopic Constituents.
Errata.

The reviewer confesses that after close inspection he has been unable to detect any errors other than those few that have been already noted on a page marked "Errata," showing very careful editing.

Finally, it may be said that the typography, paper, drawing of the numerous diagrams, woodcuts of apparatus, and photographic half-tone illustrations are unusually good.

The author is to be congratulated on the production of a book worthy of his reputation, one which will prove of permanent benefit to metallurgists as well as manufacturers of steel and iron and to workers in metals generally.

A. E. OUTERBRIDGE, JR.

PENROSE'S PICTORIAL ANNUAL. The Process Year Book for 1912-13, vol. 18, edited by William Gamble, F.R.P.S. London, A. W. Penrose and Company, Ltd. 268 pages, illustrations, plates. American agents, Tennant & Ward, New York City. Price, $3.

The eighteenth volume of this interesting annual, recently issued, contains matter of value to every one connected with the graphic arts. Specimens of the numerous processes for producing half-tone and color prints form an important feature of the volume. There are many monochrome, two-color, three-color, and four-color plates and numerous other examples of printing. The contributors include names of process workers known throughout the world, and their articles deal with the many subjects connected with the reproductive processes. An excellent portrait of Sir W. de W. Abney forms an interesting feature of the work.

CURRENT TOPICS.

Sulphuric Acid Industry in the United States. U. Wedge. (*Eighth Int. Cong. Appl. Chem., Sect. II, Orig. Comm.*, ii, 241.)—The annual consumption of sulphuric acid in the United States is approximately, when reckoned as at 50° Be., for the manufacture of phosphatic fertilizer, 2,400,000 tons; for refining petroleum products, 300,000 tons, or, taking into account its repeated use, acid equivalent to 500,000 tons is actually employed; for use in the iron and steel and coke industry, 200,000 tons; for the manufacture of nitrocellulose, nitroglycerin, celluloid, etc., 150,000 tons; and for other purposes, 200,000 tons. In 1911, 2,665,000 tons of this acid were made from pyrites; 275,000 tons from copper sulphide ores, smelted in blast furnaces; 285,000 tons from zinc sulphide ores, and 25,000 tons from brimstone. It is found most economical to erect combined sulphuric acid and fertilizer works adjacent to the agricultural districts where the fertilizer is consumed; these works are especially numerous in the Southern States where cotton is grown. Acid works are similarly located near oil refineries, and there is said to be a growing tendency for steel companies to make their own acid. Contact processes have been installed wherever nitrocellulose and similar products are manufactured, and about 10 per cent. of the total production of acid is made by one or other of the contact processes. The practice of nodulizing cinder from pyrites burners is said to have become general in all localities where there is a market for the nodulized cinder as iron ore.

"**Iron Coke.**" A. P. Lidoff. (*Eighth Int. Cong. Appl. Chem.*, 1912, *Sect. III, a, Orig. Comm.*, iii, 11.)—By passing the dust from blast furnaces repeatedly through magnetic separators a product is obtained rich in ferric oxide. One part of this dust is mixed with three parts of caking coal slack and heated to a high temperature under pressure. A porous coke is obtained, containing metallic iron regularly distributed through it. This material might be used for electrodes, or as a filtering medium, or for decolorizing solutions.

Waste and Losses in the Production of Minerals in the United States. Anon. (*Oil, Paint, and Drug Reporter*, Sept. 2, 1912.)—The Director of the United States Bureau of Mines has issued a statement describing some of the losses sustained in the yearly production of minerals in the United States. During the last year, in producing a billion tons of coal, a quarter of a billion tons were wasted or left underground; and a quantity of natural gas, larger than the total output of artificial gas during the same period in all the towns and cities of the United States, was allowed to escape. Many valuable mineral deposits are lying idle while the products are being imported from other countries. In mining coal in the United States, probably one-third of the bituminous coal and one-half of the anthracite are left in the mine. Fully 80,000,000 tons of anthracite are now being left behind in the mine each year, and it is estimated that since mining began in this country fully 2,000,000,000 tons of anthracite and 3,000,000,000 tons of bituminous coal have been left in the ground under conditions which make future recovery highly improbable. Probably not more than 11 per cent. of the energy in coal is being effectively utilized. The losses in making coke by the old-fashioned process wasted $40,000,000 in the United States last year. These coke ovens, without taking into account the value of the by-products that were possible, wasted more than 1,000,000 horsepower in the year. Almost inestimable losses of sulphur, arsenic, and bismuth are now occurring in the flue dusts and flue gases. In proportion to output, the losses of zinc are probably greater than those of any other metal, and are especially important because there is almost no recovery of zinc from manufactured products and almost no conservation of zinc by accumulation. Besides these losses in the mining and concentration of zinc ores, there are incalculable losses which undoubtedly exceed the total value of the zinc mined, in slags and waste products from other processes. In combined, but unfortunately relatively insoluble, form there are unlimited supplies of potash in the United States, but economical methods of extraction are not known. The waste of nitrogen is almost inconceivable. Although last year over 406,000,000 tons of bituminous coal were produced, only $3,800,000 of the $160,000,000 worth of recoverable nitrogen in the coal was obtained. Of 63,000,000 tons of coal converted into coke in 1910, containing $22,000,000 worth of recoverable nitrogen, only about one-sixth was treated in ovens or retorts which could make that recovery possible. The waste and the utilization of sulphur are both enormous, and depend largely on local conditions. The United States is producing annually about 3,000,000 tons of sulphuric acid, approximately one-half of which is used in the manufacture of fertilizers. The total amount of sulphur dioxide discharged into the air in the United States would unquestionably suffice to make more than 8,000,000 tons of sulphuric acid annually.

Influence of Phosphorus, Manganese, and Tin on the Physical Properties of Copper. E. MÜNKER. (*Metallurgie,* ix, 185.) —In investigating the effect of phosphorus, up to 1.06 per cent.;

of manganese, up to 1.49 per cent., and of tin, up to 1.46 per cent., on the tenacity, hardness, electrical conductivity, and density of copper in various conditions, depending upon the mechanical and thermal treatments to which the alloys were subjected, the following conclusions were reached: All three elements increase the tenacity and hardness, but decrease the elongation, electrical conductivity, and specific gravity. Annealing affects all the alloys in the same way. Tenacity and hardness are diminished, the elongation is increased, while the density and conductivity are barely affected. This paper is illustrated by 16 photomicrographs, showing the effects of annealing on the structure of the alloys.

Detection of Carbon Monoxide in Air. R. NOWICKI. (*Elektrochem. Zeitschr.*, xix, 35.)—A pocket apparatus for detecting carbon monoxide is made by C. Glatzel, Mährisch Ostrau, Austria. It consists of a U tube, fitted with two stop-cocks, and held in a wider glass tube. By alternately compressing and relaxing a rubber ball the glass tube is charged with the air to be examined. If the air contains carbon monoxide, a strip of paper moistened with palladious chloride turns brown; and if the content of carbon monoxide is more than 0.1 per cent., this occurs within one minute.

Vanadium in Pig Iron. P. W. SHIMER. (*Trans. Amer. Inst. Min. Eng.*, 1912, 883.)—The iron ore mixtures smelted in the Lehigh Valley district contain varying amounts of New Jersey magnetite in which vanadium and titanium generally occur to the extent of 0.05 and 0.60 per cent. respectively. The pig iron produced, which generally contains 0.02 to 0.05 per cent. of vanadium and 0.10 to 0.20 of titanium, is fine grained and soft and possesses unusual strength. These qualities are ascribed to the vanadium, although probably titanium has a similar action. It was found that practically the whole of the vanadium and titanium contained in such pig iron is insoluble in dilute hydrochloric acid, indicating that these elements are present in combined form, probably as carbides; even in a steel containing 0.143 per cent. of vanadium, about one-half of it was found to be present in an unalloyed state. The beneficial effect of vanadium and titanium upon pig iron is probably due to the elimination of nitrogen and oxygen, and, furthermore, they modify the structure of the metal by separating out first in finely-divided condition (probably as carbides) during the solidification, and thus provide uniformly-distributed nuclei around which the iron rapidly crystallizes. Various iron ores from other districts were found to contain from 0.006 to 0.023 per cent. of vanadium, and it is stated that it sometimes occurs in limestone and in the ash of coke. By remelting in a cupola, the vanadium content of a charge of cast iron was reduced from 0.0313 to 0.027 per cent.

Vanadium Deposits in Colorado, Utah, and New Mexico. F. L. HESS. (*U. S. Geol. Survey,* Bull. 530–K.)—Vanadium occurs at Placerville, Col., disseminated in a dull green sandstone along seams or in veins containing roscoelite, quartz, and pyrite. Carnotite appears as a lining on the joint surfaces. A sandstone of lighter green color owed its color to mariposite, a chromium mica. Near Green River, Utah, carnotite ore is reported to have been shipped containing 2.2 per cent. uranium oxide and 3.8 vanadium oxide. Vanadinite has been found at Los Caballos, New Mexico.

Bronson Resistances. FR. HAUSER. (*Physik. Zeit.,* xii, 785.)—The spherical form appears to be most satisfactory for general work. By making the radius of the sphere about 1.25 times the range of the α rays emitted by the ionizing substance, the current is then proportional to the applied potential; *i.e.,* Ohm's law holds good.

A Powerful Lamp for Ultra-violet Rays and its Use in the Sterilization of Large Quantities of Water. V. HENRI, A. HEILBRONNER, and M. DE RECKLINGHAUSEN. (*Compt. Rend.,* clv, 852.)—The lamp consists of a quartz U-tube the sides of which nearly touch one another; the diameter of the tube is 14 mm., and the length of the arms 160 mm. The two mercury electrodes are side by side. The lamp requires a current of 500 volts, with a difference of potential between the electrodes of 375 to 390 volts, with an intensity of 3 ampères. The illuminating power perpendicular to the axis is 8000 candles. Chemical reactions induced by ultra-violet rays are very greatly accelerated by the use of the new lamp. Germicidal action on *Bacillus coli* is 60 times as rapid as with a 110-volt lamp. For sterilizing large quantities of water, the lamp is placed in a cylinder of transparent quartz, which is placed in the centre of the tank through which the water passes, and the water is forced to circulate round the cylinder by a series of baffles. Thus the lamp burns as in air, and the rays are completely utilized. An installation of 8 lamps has worked 1200 hours without change, the strength of the rays being tested each day by the rapidity of the blackening of silver citrate paper exposed to them.

Petroleum Discovered in Siam. ANON. (*Oil, Paint, and Drug Reporter,* Oct. 28, 1912.)—New discoveries of petroleum have been made in Siam, located above the Tachin River, in the district north of Korat. Some villagers in Laos discovered the oil about five years ago, and draw it by means of long bamboos, reaching a depth of 60 feet. This crude oil smokes heavily when burned. It is, however, practically inaccessible, being about 200 miles from the nearest railway station.

Italian Electro-Chemical Industry in 1911. ANON. (*Chem. Trade J.*, Nov. 2, 1912.)—The official statistics for 1911, published by the Italian Ministry of Industry and Commerce, show that the production of calcium carbide was less than that of the previous year, which in turn was less than that of 1909; thus it was the lowest production of late years. Cyanamide, too, remained at a low figure, 4470 metric tons, as compared with 3715 in 1910. In the district of Rome the decrease in the production of carbide was 11,000 tons, as compared with 1910, and only four works were in operation, instead of six in the previous year. Good results, however, were obtained from the sales by the Italian General Company for the carbide trade, production being limited to the needs of the markets, which are steadily developing, owing to acetylene lighting and the manufacture of cyanamide and ammonium sulphate. At Collestate all the plant has been installed for the manufacture of cyanamide. This installation comprises three jaw crushers; three ball mills; a Linde machine for the liquefaction of air and production of nitrogen; 106 retorts, each with a capacity of 1500 kilos, to transform 3251 tons of carbide into 4000 tons of granular cyanamide, a part of which is used for the manufacture of ammonium sulphate by treatment with steam at 190° C. in three autoclaves, and the subsequent combination of the sulphuric acid with the ammonia. In the district of Bologna the Ascoli Piceno Works began normal work in 1911 and manufactured 8000 tons of carbide with three electric furnaces utilizing 6000 horsepower. Porto Ferraio, in the Florence district, has recommenced the manufacture of carbide with Stassano furnaces. The Societa Ferriere, in Milan, has reduced manufacture from 4000 tons to 2633 tons.

Recovery of Metallic Iridium. ANON. (*Eng. and Mining J.*, xciv, 802.)—Metallic iridium is made from the iridium powder left in the wet process of platinum refining. This powder cannot be melted alone, but is converted into iridium phosphide by strongly heating with stick phosphorus in a silica crucible. The iridium phosphide is then heated with lime to remove the phosphorus, leaving a brittle white mass of iridium, which cannot be filed or cut, but is broken into the small pieces necessary for pen points, which are ground into shape by carborundum. These pieces of iridium are said to be about as hard as the ruby.

New Form of Emanation Electroscope. W. HAMMER. (*Deutsch. Phys. Gesell. Verh.*, xiv, 13.)—The principle of the apparatus is that radium emanation is removed from any solution containing radium by simply shaking it. A rod leading from the vessel can be connected with any kind of electroscope and the ionization current measured. This instrument avoids any loss of emanation by transference.

Cementation of Iron by Gases. F. KUREK. (*Stahl u. Eisen,* xxxii, 1780.)—Experiments on cementation were made, using carbon monoxide, methane, and illuminating gas, and the same gases with an admixture of ammonia. The results showed that cementation with carbon monoxide at ordinary pressures cannot be used advantageously, the carburization being too slow, and that the addition of ammonia is not favorable to the formation of carbide. Methane at 800° C. had no action, but at 900° C. and 1000° C. caused considerable carburization. Illuminating gas yielded markedly higher carbon in the outer layers than methane. At 800° C. and 900° C. carburization did not penetrate far into the iron, but at 1000 C. carbide was formed throughout. Admixture with ammonia was no advantage.

Influence of Carbon on the Corrodibility of Iron. C. CHAPPELL. (*Iron and Steel Inst. Journ.,* lxxxv, 270.)—This article gives the results of investigations as to the nature and extent of the influence of increasing percentages of carbon on the corrodibility of iron. Suitable bars of practically pure carbon steels were subjected to typical heat treatments, and their relative corrodibilities determined in each of the various conditions produced by such treatment. The polished specimens were examined after 91 days' immersion in sea-water, and were then reimmersed for a further period of 75 days. The following are the chief conclusions arrived at as the result of this work: (1) *Influence of carbon on corrodibility:* (*a*) In rolled, normalized, and annealed sheets, the corrodibility rises with carbon-content to a maximum at saturation point, 0.89 per cent. carbon, and falls with any increase of carbon beyond this point. (*b*) In quenched and tempered steels a continuous rise of corrodibility occurs with the increase of carbon up to 0.27 per cent., no maximum corrodibility at saturation point being found in these steels. (2) *Influence of treatment on corrodibility:* Quenching increases the corrodibility to a maximum, annealing tends to reduce it to a minimum; normalizing gives intermediate values. The influence of tempering varies with the tempering temperature. (3) *Factors determining corrodibility:* The electromotive forces between the ferrite and the pearlite, and between the components of the pearlite itself, are the principal factors determining the corrodibility of unsaturated pearlitic steels above 0.4 per cent. carbon. In mild structural steels this galvanic action is accompanied by a further galvanic action between the ferrite crystals themselves, due to differences in their orientation. The state of division of the pearlite and the presence of internal stresses in the steel may exert some influence on the foregoing factors. (4) *Influence of time on corrodibility:* The influence of time on the rate of corrosion varies with different steels. In a low-carbon steel it is found to be practically directly proportional to the length of time of immersion. (5) The influence of corrosion on the resistance offered by a low-carbon steel to alternating stress is not appreciable within a period of 5 months' immersion. (6) Three per cent. of tungsten has no effect on the corrodibility of carbon steels. (7) Decarbonization increases the resistance to corrosion. (8) The two oxides, ferrous oxide and the ferro-ferric (magnetic) oxide, both exert a microscopical pitting effect on steel when in contact with it in sea-water.

Production of Electric Steel. ANON. (*Mining and Eng. World,* Nov. 12, 1912.)—The production of steel in electric furnaces during the last three years was, in tons:

	1909	1910	1911
Germany	17,773	36,188	66,654
United States	13,762	52,141	29,105
Austria-Hungary ..	9,046	20,028	22,867
France	6,456	11,759	13,850
	47,037	120,116	132,476

The United Kingdom had hardly commenced to produce for the general market. The predominating lead of Germany and the drop in the electric steel production of the United States are notable features of last year's figures. Activity in France lies more in the field of ferro-alloys. Of these France made altogether, in 1904, 34,200 tons, which was increased to 60,200 tons by 1910. The ferro-alloys made in electric furnaces were respectively 5756 tons and 23,800 tons. The electrically-produced alloys in 1909 amounted to 14,900 tons, and varied little in the years 1906 to 1909.

Composition of Thorianite. M. KOBAYASHI. (*Science Reports, Tôhoku Imp. Univ., Sendai, Japan,* i, 201.)—An examination of specimens of thorianite indicated that there are two varieties of the mineral, one containing about 78 per cent. of thorium oxide and 15 per cent. of uranium oxide, a molecular ratio of thorium oxide to uranium oxide = 6 : 1; and the other about 60 per cent. of thorium oxide and 33 per cent. of uranium oxide, a molecular ratio of thorium oxide to uranium oxide = 2 : 1. Different results hitherto obtained may be explained by the assumption that mixtures of the two varieties in varying proportions were analyzed. Dunstan and Jones described a thorianite from Ceylon rich in uranium, and expressed the view that in thorianites the thorium and uranium oxides are not in chemical combination, but are present as isomorphous mixtures. Against this view the author points out that the simple molecular ratio of the two oxides can hardly be a coincidence; and that, whilst ignited thorium oxide is nearly insoluble in nitric acid, thorianite dissolves fairly readily, even after ignition.

Copper Alloy Resistant to Acids. Robert Grimshaw. (*The Metal Industry,* x, 12, 498.)—An alloy of 40 per cent. cobalt and 60 per cent. tin is especially resistant to acids, even to concentrated nitric acid and to this acid mixed with chlorides. It is, however, so brittle as to be unworkable, and is therefore practically worthless. If, however, this alloy is dissolved in copper, so as to form a new alloy of 80 to 95 per cent. copper and 20 to 5 per cent. of the cobalt and tin, a series of alloys is obtained which may be filed, bored, turned, forged, etc., and also have a high degree of chemical resistance. It has been found preferable to make the cobalt-tin alloy first and then dissolve that in the copper.

Opacity to X-Rays. L. G. Droit. (*Comptes Rendus,* clv, 706.)—Silk fabrics were loaded with lead phosphostannate, by the ordinary processes of mordanting with metallic salts. One such fabric weighed 266 Gm. per square metre, and 68 per cent. of its weight consisted of mineral matter (lead oxide 34, stannic oxide 24, phosphoric anhydride 8, lime and alkali 2). Two layers of this were found to be so slightly permeable by "soft" discharges, and six layers by medium or ordinary discharges, as to form an efficient protection against the injurious effect of X-rays on the skin. At the same time the covering with six layers was sufficiently flexible for work. This fabric had an opacity equivalent to a sheet of copper 0.044 mm. thick.

Melting Points of Firebricks and Clays. Anon. (*Brass World,* viii, 12, 432.)—The Bureau of Standards recently determined the melting points of firebricks in an accurate way. The results are interesting as indicating the commercial value, with regard to their heat-resisting properties, of the various kinds of firebricks. The results obtained were:

Fire clay brick	1555° to 1725° C.
Bauxite brick	1565° to 1785° C.
Silica brick	1700° to 1705° C.
Chromite brick	2050° C.
Magnesia brick	2165° C.
Kaolin	1735° to 1740° C.
Bauxite	1820° C.
Bauxite clay	1705° C.
Chromite	2180° C.
Pure alumina	2010° C.
Pure silica	1750° C.
Carborundum	2700° C.

The value of 1750° given for silica is not the true melting point, but represents the temperature at which the silica distinctly flows.

The Second Law of Thermodynamics.—C. P. STEINMETZ. (*Engineer*, cxiv, p. 103. *From the "General Electric Review."*)—The second law of thermodynamics is discussed and several popular misconceptions with regard to it are referred to. It is concluded that the second law of thermodynamics is not a universal law of nature, but applies only within the limited range of thermodynamic engines from which it has been derived. It does not apply to the universe as a whole; and the conclusion sometimes deduced from it, that the universe must finally come to a standstill, is not justified. (This is in accordance with Nernst's own statement, that the laws of Physics, in general, are only true within certain limits.—ABSTRACTOR.)

Influence of Pouring Temperature on Aluminum Alloys. H. W. GILLETTE. (*Eighth Int. Congr. Appl. Chem., Sect. II, Orig. Comm.*, ii, 105.)—Comparative experiments on the tensile strength of castings of aluminum and a series of aluminum alloys were made with a view to ascertain the effect of the pouring temperature on this property; it was shown that, on the average, bars poured hot, at 815° to 871° C., are nearly 20 per cent. weaker than bars of the same material poured cold, at 649° to 704.5° C., owing to the slower crystallization in the former case, and it is suggested that in all tests of cast aluminum alloys the pouring temperature should be recorded as well as the dimensions of the test piece and the composition of the mould. These also affect the rate of crystallization, *i.e.*, the fineness of grain, of the metal. The addition of small amounts of manganese, titanium, iron, or antimony to the alloy containing 8 per cent. of copper (that most used for casting) was found to increase the strength when poured hot, but at the same time to cause brittleness and to decrease the resistance to impact. It is stated that at the most modern foundries aluminum castings are now poured at the lowest temperature at which the mould will fill, without forming blow-holes. It was found that platinum thermo-couples are unsuitable for taking the pouring temperature, owing to "lag"; and the use of base metal couples or "fire rods, of the welded end, rod, and tube type," are recommended.

Absorption of Ultra-violet Vibrations by Radioactive Elements of their Degradation Products. N. D. ZELINSKY. (*Acad. Sci. St. Petersbourg Bull.*, vi, 465.)—The author's measurements of the absorption spectra of radioactive and other substances show that the activity of elements obtaining their energy from some unknown source, probably from the internal, potential energy of the atom, is exhibited in the absorption of ultra-violet light, both by the active materials themselves and by their emanations. This new method of detecting the presence of radioactive substances increases the methods now available to five.

Improvement in Yield of Open-hearth Steel. F. W. PAUL. (*Iron and Steel Inst.*, Sept., 1912.)—A review is given of the ordinary practice of open-hearth steel manufacture with special reference to the yield obtained, after which a new method of charging and of eliminating silicon is proposed. *Charging.*—After the pig iron is all charged and the silicon sufficiently removed to permit the metal to be superheated without loss, the steel scrap is charged in such quantities as to allow the bath to remain molten. *Melting.*—The pig iron and scrap floating in a molten bath of metal with a protective coating of slag is thus protected from the oxidizing atmosphere of the furnace, and less waste ensues and the yield is increased. By this means the melting stage and the silicon elimination stage are merged into one, and the silicon is removed during a period of six hours or more with the metal at a low temperature, and therefore the scouring action on the " banks " is considerably diminished and the temperature of the iron and the content of oxide of iron in the slag can be controlled so that the reaction takes places without the emission of brown smoke. The following important features of these proposals have been practically confirmed in a 70-ton furnace: (1) A very decided increase in yield. (2) The practicability of so superheating the de-siliconized metal as to permit the addition of cold steel scrap without causing partial solidification of the charge. (3) Charges of all-pig iron can be worked with considerable increase in yield compared with charges of pig iron and scrap. (4) The brickwork of the furnace is not subjected to such extreme fluctuations of temperature. (5) During the melting stage the level of the metal in the furnace is continually altering, and thus the scouring action on the thin top part of the " banks " avoided, and there is less loss of time for repairs and less risk of " breakouts." (6) The prevention of oxide of iron fumes will probably lengthen the life of the chambers.

Combination of the Contact Process with the Lead Chamber or Tower Systems in the Manufacture of Sulphuric Acid. W. WILKE. (*Eighth Int. Congr. Appl. Chem.*, Sect. II, *Orig. Comm.*, ii, 249.)—The gases from the pyrites burners are conducted into an iron oxide contact shaft, in which the sulphurous gases undergo conversion into sulphur trioxide to the extent of about 30 per cent., and thence are driven by a fan through the Glover tower to the chambers. The combination of the two processes is said to increase the capacity of the chamber plant by at least 30 per cent., and to allow of more uniform working, besides effecting a saving of 30 per cent. in the nitre consumed. It was found that the total production of the chamber system could easily be concentrated to 60° Be. or higher in the Glover tower, and the acid produced was colorless. The iron oxide also eliminates 95 per cent. of the arsenic carried by the gases, and prevents dust from reaching the chambers.

Tartaric Acid and Cream of Tartar. ANON. (*Oil, Paint, and Drug Reporter,* Oct. 14, 1912.)—The United States Treasury Department has issued the following instructions to collectors of customs at ports where laboratories of the Department of Agriculture are established: "That refined tartaric acid and cream of tartar containing lead in excess of 20 milligrammes per kilogram shall be held as adulterated, under section 7, paragraph 5, under Foods, in that they contain an added poisonous and deleterious ingredient which may render the product injurious to health."

American Petroleum. ANON. (*Eng.,* xciv, 2438, 407.)—The petroleum area of the United States is estimated at 8850 square miles. Alabama has 50 square miles; Alaska, 500; California, 850; Colorado, 200; Idaho, 10; Illinois, 200; Indiana, 1000; Kansas, 200; Kentucky, 400; Louisiana, 60; Michigan, 80; Missouri, 30; New Mexico, 80; New York, 300; Ohio, 650; Oklahoma, 400; Pennsylvania, 2000; Tennessee, 80; Texas, 400; Utah, 40; West Virginia, 570; and Wyoming, 750 square miles.

A New, Cheap White Metal Alloy. ANON. (*Brass World,* viii, 12, 435.)—This new alloy, containing a large proportion of iron, has been patented by John F. Duke, of Manchester, England, in U. S. Patent 1,044,761 of 1912. The proportions are: iron, 50.30 per cent.; nickel, 19.16; copper, 29.14, and aluminum, 1.40 per cent. It is white, non-corrosive, and resists the action of vegetable acids and the atmosphere well. If more hardness is desired, add from 1 to 2 per cent. of tin.

Supposed Loss of Nitrogen in Calcium Cyanamide (Nitrolim). G. LIBERI. (*Ann. R. Staz. Chim. Agrar. Sperim. di Roma,* v, 163.)—Experiments were made to settle the conflicting statements as to the loss of nitrogen from crude calcium cyanamide on keeping, such loss being ascertained by determining the actual ammonia evolved. It was found that under the most severe conditions, such as exposure for 50 days in a constantly-changing atmosphere, saturated with water vapor, the loss of nitrogen only amounted to 3.06 per cent. of the total nitrogen in the original material. Considering the severity of the conditions, the author concludes that in practice, when the material is usually in sacks or similar containers, so that relatively a much smaller surface is exposed, and the conditions are less severe, the loss of nitrogen is practically negligible, especially if the fertilizer be kept in a dry atmosphere.

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ON THE PHYSICS OF THE ATMOSPHERE.[1]

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INTRODUCTION.

THE physical phenomena of the earth's atmosphere are exceedingly numerous and often owe their origin to a plurality of causes. Nevertheless they can be just as accurately described and, in general, just as satisfactorily explained as can phenomena of the laboratory, from which, indeed, they differ but little save in extent and complexity. In fact, with but few exceptions, meteorological phenomena are wholly physical phenomena, and meteorology itself, as distinguished from climatology, a most interesting branch of applied physics. Happily, too, because of its valuable applications, it is a science that is rapidly being developed.

FUNDAMENTAL FACTS.

In what follows, the physical explanations of certain atmospheric phenomena will be briefly explained. But first, as a helpful introduction, it may be well to consider a sort of a cross

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[1] Presented at the meeting of the Section of Aërial Navigation and Aëronautics held Thursday, January 23, 1913.

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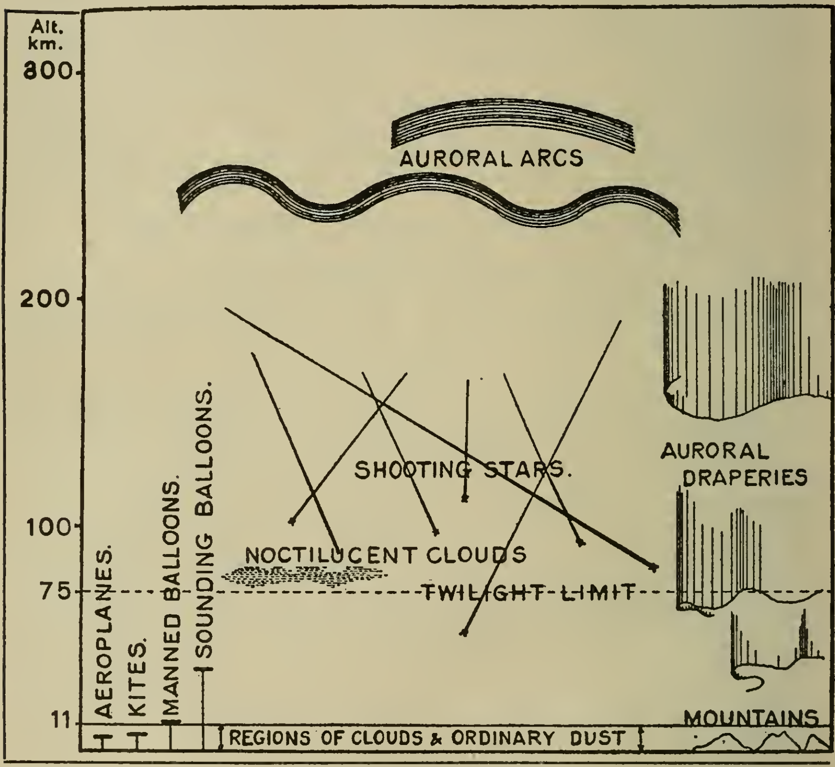
section of the atmosphere as a whole with reference to the sources of meteorological information concerning each particular region, and then to follow this by other cross sections that give its temperature, pressure, and composition at various levels. One or more of these general considerations is fundamental to an understanding of almost any detail in the physics of the atmosphere, and hence they should constitute, as stated above, an introduction helpful to anyone who wishes to make a serious study of this important subject.

FIG. 1.



Sources of meteorological information.

Sources of Information.—Fig. 1, an adaptation of Wegener's[1] Profile of the Atmosphere, indicates the principal sources of meteorological information and the distribution of phenomena at various levels.

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[1] *Phys. Zeitsch.*, 12 Jahrg. 1911, p. 170.

Mountains and other irregularities of the earth's surface enable us to explore the atmosphere from sea level up to about 7 kilometres, beyond which elevation man has not yet been able to climb. But, of course, in this case the surface conditions, whatever they may be, are always present, and hence some other means of gathering information must be adopted if we would know the conditions and movements of the free atmosphere. One obvious source of the desired information, and one that has been extensively used, is the movement of clouds, which, as is generally known, occurs at all levels from the land or ocean itself up to 11 kilometres, or thereabout, in middle latitudes and occasionally even as high as 15 kilometres in the tropics.

The elevation, direction of motion, and velocity of clouds are all easily determined by the aid of appropriate apparatus, and hence the direction and velocity of the wind at the same time and place are known. However, this is nearly all the positive information about the atmosphere that clouds do give, and besides they are by no means always present, so that on clear days even this information would be lacking if we had no other means of investigation. But then there are other means, and, in several respects, means far more valuable than the measuring of clouds, of gaining information in regard to the free air. The most valuable of these is the use of self-registering thermometers, barometers, hygrometers, and the like on:

(*a*) Aëroplanes; present limit about 6 kilometres.

(*b*) Kites; up to 7 kilometres.

(*c*) Manned balloons; maximum elevation roughly 11 kilometres.

(*d*) Sounding balloons; with a record of more than 30 kilometres.

The registering apparatus sent aloft by these various methods furnishes reliable information about the composition (including humidity), temperature, pressure, direction of motion and velocity of the atmosphere, from the surface of the earth up to the greatest elevations reached. And it is this automatically recorded information, gathered, with but little exception, during only the past few years, that has so greatly extended our accurate knowledge of meteorology, and done so much to make of it a thoroughly respectable branch of physics.

Beyond the reach of the sounding balloon, or at greater elevations than 30 kilometres, our information of the atmosphere is limited to such deductions as may properly be drawn from the height of the twilight arch, roughly 75 kilometres; the paths of shooting stars, rarely if ever seen as high as 200 kilometres; and the appearance and field of auroras, curious and but partially explained electrical discharges seldom occurring lower than 30 kilometres or higher than 300.

These, then, are all, or nearly all, the means by which our knowledge of the atmosphere has been obtained. Up to 30 kilometres it is comparatively well known; beyond that level only deduction, growing less certain with elevation, can possibly take us at the present, or any time until higher soundings are made.

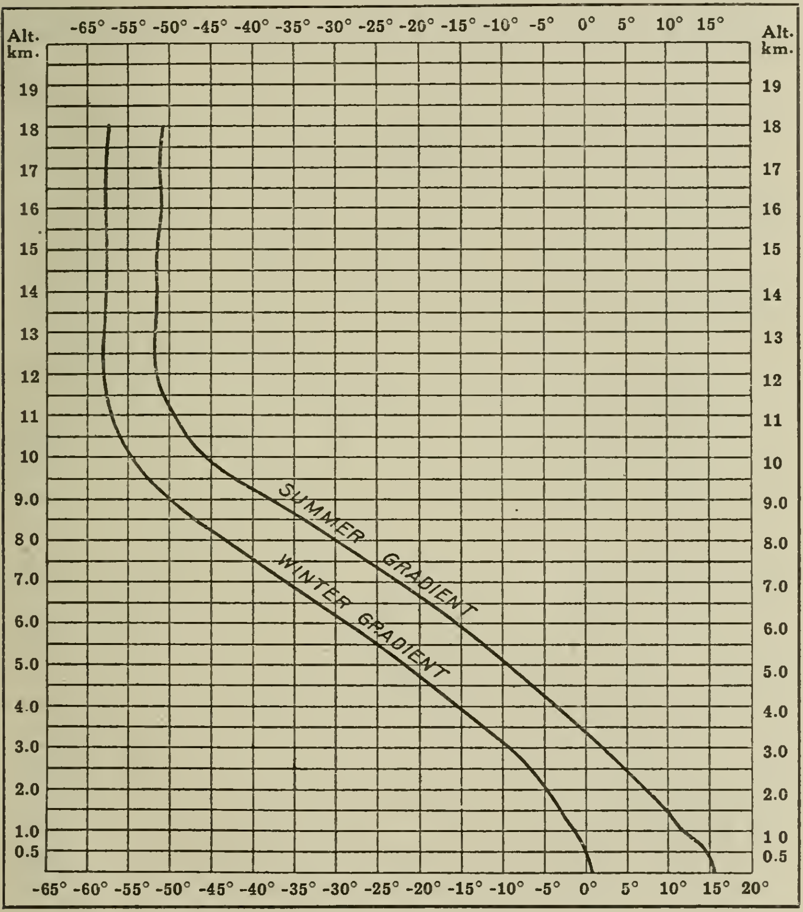
Temperature Gradients.—We will now consider the temperature of the atmosphere at different levels, and as this varies more or less from day to day, as well as from place to place and season to season, averages will be given of values obtained by sounding balloons.

A curve obtained by plotting temperature against altitude is known as a vertical temperature gradient, and serves the purpose of showing graphically not only the actual temperature at any given altitude but also the rate and sense of change of temperature with change of altitude.

Fig. 2 shows both a winter and a summer vertical temperature gradient as determined by averaging 52 and 65 records, respectively, obtained by sounding balloons sent up from Munich, Strassburg, Trappes, and Uccle, all of which stations are comparable in the sense that they do not differ greatly in latitude and have more or less similar climates. A larger number of observations would give averages closer to the actual normal, but the general results certainly would remain the same. The two gradients, it will be observed, are roughly parallel throughout the entire region examined, except the lowest two or three kilometres, where the departure may easily be explained by the differences, in the two seasons, of the ordinary daily convection.

The vertical temperature gradient at any given time, as determined by sounding balloon records, differs more or less, as a rule, throughout its course, from the average or normal gradient. This difference, however, is not particularly misleading except in those upper levels (10 to 12 kilometres in the given figure) where the average gradient shows a *gradual change* in the rate of temperature decrease. As a matter of fact, the actual transition from maximum to minimum rate of temperature decrease

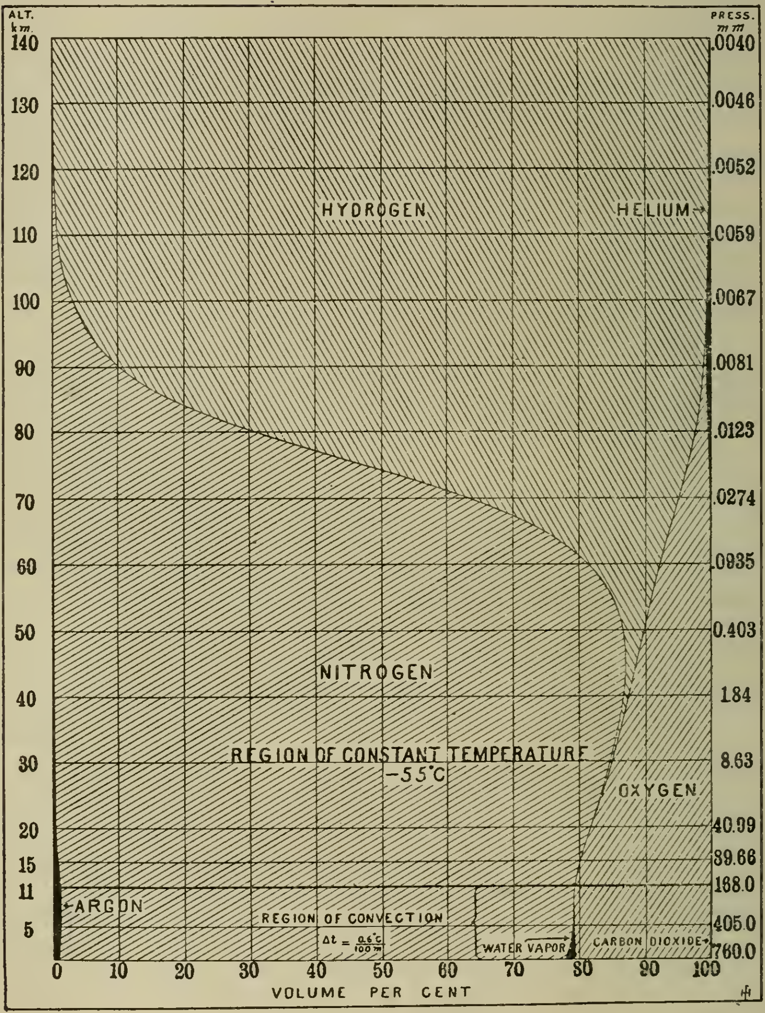
FIG. 2.



Winter and summer vertical temperature gradients.

usually is faster than the average gradient would indicate; indeed, it often is so quick as to appear abrupt, while in some cases it even inverts into a rapid, though generally slight, temperature increase. However, both the level and the temperature at which these rapid transitions take place vary from day to day, and hence, on being averaged, a deceptively gradual and regular transition is indicated.

FIG. 3.



Composition of the atmosphere.

Composition of the Atmosphere.—Fig. 3, drawn in accordance with Table I, graphically represents the approximate composition of the atmosphere at various levels. The assumptions upon which it is based are in close agreement with the average conditions of middle latitudes, and are as follows:

1. That at the surface of the earth the principal gases of the atmosphere and their respective volume percentages in dry air are:

Nitrogen	78.03	Hydrogen	0.01
Oxygen	20.99	Neon	0.0015
Argon	0.94	Helium	0.00015
Carbon dioxide	0.03		

2. That water vapor at the surface of the earth amounts to 1.2 per cent. of the total quantity of gas present.

3. That the water vapor rapidly decreases, under the influence of lower temperatures, with increase of elevation, to a negligibly small amount at or below the level of 10 kilometres.

4. That the temperature decreases uniformly at the rate of 6° C. per kilometre from 11° C. at sea level to —55° at an elevation of 11 kilometres.

5. That beyond 11 kilometres above sea level the temperature remains constant at —55° C.

6. That up to the level of 11 kilometres the relative percentages of the several gases, excepting water vapor, remain constant—a result, of course, of vertical convection.

7. That above 11 kilometres, where the temperature changes but little with elevation, and where vertical convection, therefore, is practically absent, the several gases are distributed according to their respective molecular weights.

A number of atmospheric gases—neon, krypton, xenon, ozone, etc.—are omitted both from Table I and from its accompanying figure. This is because all these occur—in the lower atmosphere, at any rate—in quantities too small for graphical illustration in the same diagram and to the same scale as are the principal gases.

In using this diagram it should be distinctly remembered that it is supported by direct experimental observations only from the surface of the earth up to a level of about 30 kilometres, and that while the extrapolated values are based upon apparently sound logic and not upon mere surmises, still they necessarily become less and less certain with increase of elevation.

From the surface of the earth up to 11 kilometres elevation the variation of pressure with altitude must be computed according to Ferrel's or some similar equation that takes account of the effect of temperature change. But from this level on the process is greatly simplified because of the constant temperature. Thus the percentage of each gas is multiplied by the total pressure at the elevation of 11 kilometres to find its own independent or partial pressure at that elevation, and its pressures at other elevations are then determined by the simple equation

$$-dB = B\frac{dh}{H}$$

in which dB is the change in the partial pressure due to the change dh in the elevation, B the initial partial pressure and H the virtual height of the gas in question or height, assuming its density throughout to be the same as at the given level, necessary to produce the pressure B. This neglects the change in the force of gravity with change of latitude and with change of elevation, but for a fairly close first approximation it is quite sufficient. It is not convenient, however, for numerical calculations, and therefore to adapt it to the computation of Table I it was put in the form

$$\text{Log}_{10} B = \text{Log}_{10} B' - \frac{0.434295}{H}(h - h')$$

This adapts the equation to the use of ordinary logarithms and renders the computations easy. H, of course, is different for different gases, but for each one it is known for any given temperature and pressure.

The table and the figure bring out a few points not generally realized. One of these is the fact that the total amount of argon in the atmosphere is much greater than the average total amount of water vapor. Another is the surprisingly small amount of water vapor, especially in view of the wonderful things it does, and of its vital importance to life of every kind. There may also be a little surprise that, according to calculation, the percentage of water vapor reaches a certain maximum at an elevation of 70 to 80 kilometres, where it is, roughly, twentyfold what it is at, say, 11 kilometres. But this does not mean that the total amount of water vapor increases with elevation, but only that it decreases less rapidly than do the heavier constituents, and more rapidly than the two lighter ones, hydrogen and helium.

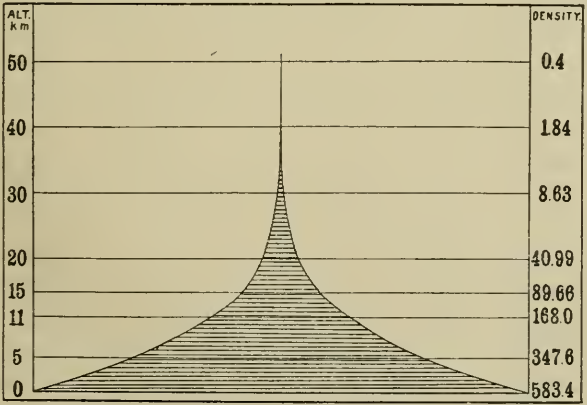
TABLE I.

Percentage Distribution of Gases in the Atmosphere.

Height in kilometres	GASES.							
	Argon.	Nitrogen.	Water vapor.	Oxygen.	Carbon dioxide.	Hydrogen.	Helium.	Total pressure in millimetres.
140	....	0.01	....	.....	....	99.63	0.36	0.0040
130	....	0.04	....	.....	....	99.55	0.41	0.0046
120	....	0.19	....	.....	....	99.35	0.46	0.0052
110	....	0.68	0.02	0.02	....	98.77	0.51	0.0059
100	....	2.97	0.05	0.11	....	96.31	0.56	0.0067
90	....	9.86	0.10	0.49	....	88.97	0.58	0.0081
80	....	32.39	0.17	1.86	....	65.11	0.47	0.0123
70	0.03	62.04	0.20	4.74	....	32.73	0.26	0.0274
60	0.03	81.33	0.15	7.70	....	10.69	0.10	0.0935
50	0.12	86.82	0.10	10.17	....	2.76	0.03	0.403
40	0.22	86.43	0.06	12.61	....	0.67	0.01	1.84
30	0.35	84.27	0.03	15.18	0.01	0.16	....	8.63
20	0.59	81.24	0.02	18.10	0.01	0.04	....	40.99
15	0.77	79.52	0.01	19.66	0.02	0.02	....	89.66
11	0.94	78.02	0.01	20.99	0.03	0.01	....	168.00
5	0.94	77.89	0.18	20.95	0.03	0.01	....	405.
0	0.93	77.08	1.20	20.75	0.03	0.01	....	760.

Density of the Atmosphere.—Fig. 3, though serving the useful purpose of graphically representing the percentage distribution of the several gases of the atmosphere, is nevertheless likely to be misleading in respect to their combined density, especially at great elevations. This latter information is shown by Fig. 4, in

FIG. 4.



Density of the atmosphere.

which the width at every altitude is proportional, approximately, to the corresponding atmospheric density, or at least to as great an elevation, about 40 kilometres, as the size of the figure will permit. Indeed, the density decreases so rapidly with increase of elevation that if at the level of 140 kilometres it is represented by a line only one one-hundredth of an inch long, then at sea level, taking into account difference in temperature and in composition, it would require for its full representation to the same scale a line whose length was, roughly, 1800 feet. Obviously, therefore, the density of the atmosphere throughout its known range of, say, 250 kilometres cannot be graphically represented on any one scale.

THE ISOTHERMAL REGION.

One of the above introductory or fundamental graphs, Fig. 2, represents information but recently acquired, and itself needs interpretation. Indeed, the discovery of the fact that the temperature of the upper atmosphere changes but little with altitude, and the supplementary discovery of its physical explanation, constitute probably the most important advances in modern meteorology.

About a dozen years ago Teisserenc de Bort began sending up free balloons with self-registering thermometers, and soon found temperature records that indicated something unsuspected: either unsuspected errors in the thermometers themselves or unsuspected temperature conditions in the upper atmosphere. However, numerous temperature records subsequently obtained by Teisserenc de Bort, by Assmann, by Hoormann, by Rotch, by Petavel, and by many others in various countries and with different kinds of apparatus have shown that, in general, the temperature of the upper atmosphere actually does change but little with change of elevation. Indeed, as a rule, the change is so small that the whole region characterized by this approximate constancy of temperature has been called the "isothermal region."

The height at which this region begins and its temperature both depend upon season, upon storm conditions, and upon latitude; but, while all these are important details, they are secondary to the fact that there is an isothermal region at all. As soon as observations left no doubt of the actual existence of the isothermal region many hypothetical explanations of it were suggested, but for a number of years all such suggestions proved unavailing. Finally, however, independently and nearly simultaneously, the generally-accepted explanation occurred to Gold [2] of England and to Humphreys [3] of America. The key to their explanation is this: The temperature of every portion of the atmosphere is determined, in part at least, by counteracting radiation, by radiation absorbed, and by radiation emitted, and wherever these two are equal there is substantial constancy of temperature.

Mr. Gold's method of procedure was to take the best-known data concerning atmospheric absorption and radiation and to obtain, by the aid of suitable mathematics, a general solution of the problem. The chief difficulty in the application of this direct and elegant method, apart from the troublesome equations involved, is due to our imperfect knowledge of the necessary radiation and absorption constants. Numerical values in these particulars are not accurately known and certainly are not easy to determine.

On the other hand, the solution offered by Humphreys, while not so straightforward and direct, reduces the necessary mathematics to almost a zero minimum. In brief it is as follows: Since the average yearly temperature of the atmosphere at any given place does not greatly change, it follows that the absorption of solar radiation by the earth as a whole is substantially equal to the total of outgoing earth radiation, and in amount approximately equal to that which a blank or perfectly radiating surface, equal in area to the surface of the earth, would emit when at the absolute temperature 259° C.[4] Further, since at ordinary atmospheric temperatures water vapor, in any considerable quantity, absorbs and, presumably, also radiates substantially as does a black body at the same temperature, while dry air is exceedingly diathermanous, it follows that the planetary radiation of the earth is essentially water vapor radiation.

Now the records of sounding balloons show that at some altitude, in general about 11 kilometres above sea level in middle latitudes, the average temperature ceases to decrease with increase of elevation. Individual flights show many peculiarities that call for special explanation, but the purpose here is to consider only the general explanation of the main effect, and therefore average conditions are considered.

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[2] *Proc. Roy. Soc.*, Series A, vol. 82, 1909, p. 43.

[3] *Astrophys. Jour.*, vol. 29, 1909, p. 14.

[4] Abbot and Fowle, Annals of the Astrophysical Observatory of the Smithsonian Institution, vol. 2, p. 174.

If, then, as is approximately true, the temperature does not decrease with increase of altitude above 11 kilometres, it follows that this must be the limit of anything like a marked vertical convection. And from this in turn it follows that the upper atmosphere must be warmed almost wholly by absorption of radiation, in part solar and in part terrestrial; but exactly how much of the final temperature of the upper atmosphere is due to the one source of heat and how much to the other it is not possible to say. However, there are certain facts that seem clearly to indicate the relative importance of the two. Thus the summer and winter gradients as given by Fig. 2 show a difference of temperature in the isothermal region of only about the amount that might be expected on the assumption that the temperature of the upper air is wholly dependent upon the radiation from the lower. That is to say, the seasonal temperatures of the lower atmosphere differ distinctly more than do those of the upper. It should be distinctly remembered, too, that the particular seasonal gradients given in Fig. 2 were obtained at a latitude of, roughly, 50° where the number of hours of summer and winter sunshine differ greatly, and therefore where the seasonal temperature of the isothermal region, if essentially determined by absorption of solar radiation, should differ somewhat correspondingly. But as no such great difference in these temperatures does exist, it would appear that the temperature of the isothermal region must be due chiefly to absorption of long wavelength radiation given off by the water vapor and other constituents of the atmosphere at lower levels. Hence, as a first approximation, we will consider this radiation alone, and for the lower atmosphere as it actually exists we will substitute the radiationally equivalent black shell at the absolute temperature of 259° C. Obviously, too, this surface, surrounding as it does the entire earth, may be regarded as horizontal and of infinite length and breadth in comparison to any elevation attainable by sounding balloons.

Now consider two such surfaces, parallel and directly facing each other, with distance apart small in comparison to their width, and having the same absolute temperature T_2, and let an object of any kind whatever be placed at the centre of the practically enclosed space. Obviously, according to the laws of radiation, the final temperature of the object in question will also become approximately T_2. If now one of the parallel planes should be removed, the exposed object would be in substantially the same situation, so far as exposure to radiation is concerned, as is the atmosphere of the isothermal region in its exposure to the radiation from the lower atmosphere. Hence the problem is to find the final temperature to which an object, assumed infinitesimally small, to fit the case of a gas, will come when exposed to the radiation of a single infinite black plane.

In each case,—that is to say, when between the parallel planes and when facing but one,—temperature equilibrium is reached when the loss of energy by radiation is equal to its gain by absorption. Also, so long as the chemical nature of the object remains the same, its coefficient of absorption is but little affected by even considerable changes in temperature, and therefore, whatever the nature of the object, since it is exposed to twice as much radiation when between the two planes as it is when facing but one, it must, in the former case, both absorb and emit twice as much energy as in the latter. Or, using symbols,

$$E_2 = 2E_1$$

in which E_2 and E_1 are the quantities of heat radiated by the object, per second, say, when between the two planes and when facing but one, respectively.

Again

$$E_2 = K_2 T_2^{n_2}$$

and

$$E_1 = K_1 T_1^{n_1}$$

in which T_2 and T_1 are the respective absolute temperatures of the object under the given conditions, and K and n the radiation constants.

For every substance there are definite values of K and n which, so long as the chemical nature of the object remains the same, do not rapidly vary with change of temperature. Hence, assuming $K_2 = K_1$ and $n_2 = n_1$, we have, from the equation

$$E_2 = 2E_1$$
$$T_2 = \sqrt[n]{2}\, T_1$$

From this it appears that there must be some minimum temperature T_1 below which the radiation of the lower atmosphere will not permit the upper atmosphere to fall, though what it is, for a given value of T_2, depends upon the value of n.

Presumably the radiation of the upper atmosphere is purely a thermal radiation, and therefore in full agreement, as is the thermal radiation of water vapor, carbon dioxide, and certain other gases, with the Kirchhoff law.[5] In other words, the ratio of emission to absorption for any given wave-length, presumably, is wholly a question of temperature and is numerically equal to the radiation of a black body at the same temperature and wave-length. In symbols

$$\left(\frac{He}{h}\right)_{\lambda,t} = (E)_{\lambda,t}$$

in which H is the incident energy, h the energy absorbed, and e the energy emitted by the body or gas in question at the wave-length λ and temperature t, and E the black body emission at the same wave-length and temperature, all per equal area and time.

To fix the ideas, let the body of gas under consideration be a shell one centimetre thick, surrounding the earth at a fixed distance—20 kilometres, say, above sea level—and let the black body be an infinitely thin shell and therefore at the same temperature inside and out, that may, if we wish, take the place of the gas shell. We can now consider the incident radiation to be normal if we like, on one side, and the emitted radiation to be all the energy sent out by the shell on *either* or on *both* sides; only, whatever the assumption for one shell, the same must be made for the other.

Returning to a consideration of the temperature of the upper atmosphere under the influence of radiation from the lower gases:

Since the composition of the upper atmosphere is not appreciably changed by a change of even 50° C., it follows that such a change of temperature will not materially alter its coefficient of absorption. Hence a change in the intensity of the incident radiation H will make substantially the same proportionate change in the rate of absorption h, whatever the alteration in temperature. In short,

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[5] Pringsheim, *Congrés International de Physique,* Paris, 1900, vol. 2, p. 127.

$$\frac{H}{h} = K, \text{ a constant, presumably.}$$

Hence

$$\frac{e_{\lambda,t_1}}{e_{\lambda,t_2}} = \frac{E_{\lambda,t_1}}{E_{\lambda,t_2}}$$

or

$$\frac{e_{\lambda,t_1}}{E_{\lambda,t_1}} = \frac{e_{\lambda,t_2}}{E_{\lambda,t_2}}$$

Unfortunately, nothing is known of the spectral distribution of the energy radiation of the cold upper atmosphere, though possibly it is of the irregular, but more or less continuous, broad band type. If this is its distribution and if for each wave-length the increase of black body radiation, for a small increase of temperature, is proportional to the total radiation at that wave-length which it is to a rough first approximation, then to about the same average approximation

$$\frac{e_{t_1}}{e_{t_2}} = \frac{E_{t_1}}{E_{t_2}},$$

in which the symbols stand for the total radiation of all wave-lengths.

But from the Stefan law in regard to the total radiation of black bodies, we know that

$$\frac{E_{t_1}}{E_{t_2}} = \frac{T_1^4}{T_2^4}$$

in which T_1 and T_2 are the respective absolute temperatures.

Hence, if, as explained above, the spectral distribution of the radiation of the upper atmosphere is continuous, or nearly so (no matter how irregular), and not confined chiefly to lines, with zero radiation between them, it follows that in the equation

$$T_2 = \sqrt[n]{2}\ T_1,$$

the numerical value of n must be 4, roughly. But, as already explained, the value of T_2 is substantially 259° C. absolute; hence, on the assumption that $n=4$, it follows that $T_1=218°$ C. absolute. And this is the value, approximately, that observation gives.

Whatever the facts in regard to the radiation constants of the atmosphere, the laws of radiation and absorption demand that the temperature of the upper atmosphere shall change but little with change of elevation. Besides, while the exact value of this temperature—the temperature of the isothermal region—is, of course, best determined by actual observation, it also may be approximately computed from the known intensity of outgoing radiation, together with the thermal properties of the gases of the atmosphere.

Doubtless solar radiation affects the temperature of the isothermal region to some extent, but, presumably, not very much, since the radiation from the lower levels seems competent not only to produce an isothermal condition in the upper levels but also to maintain them at approximately the observed temperature.

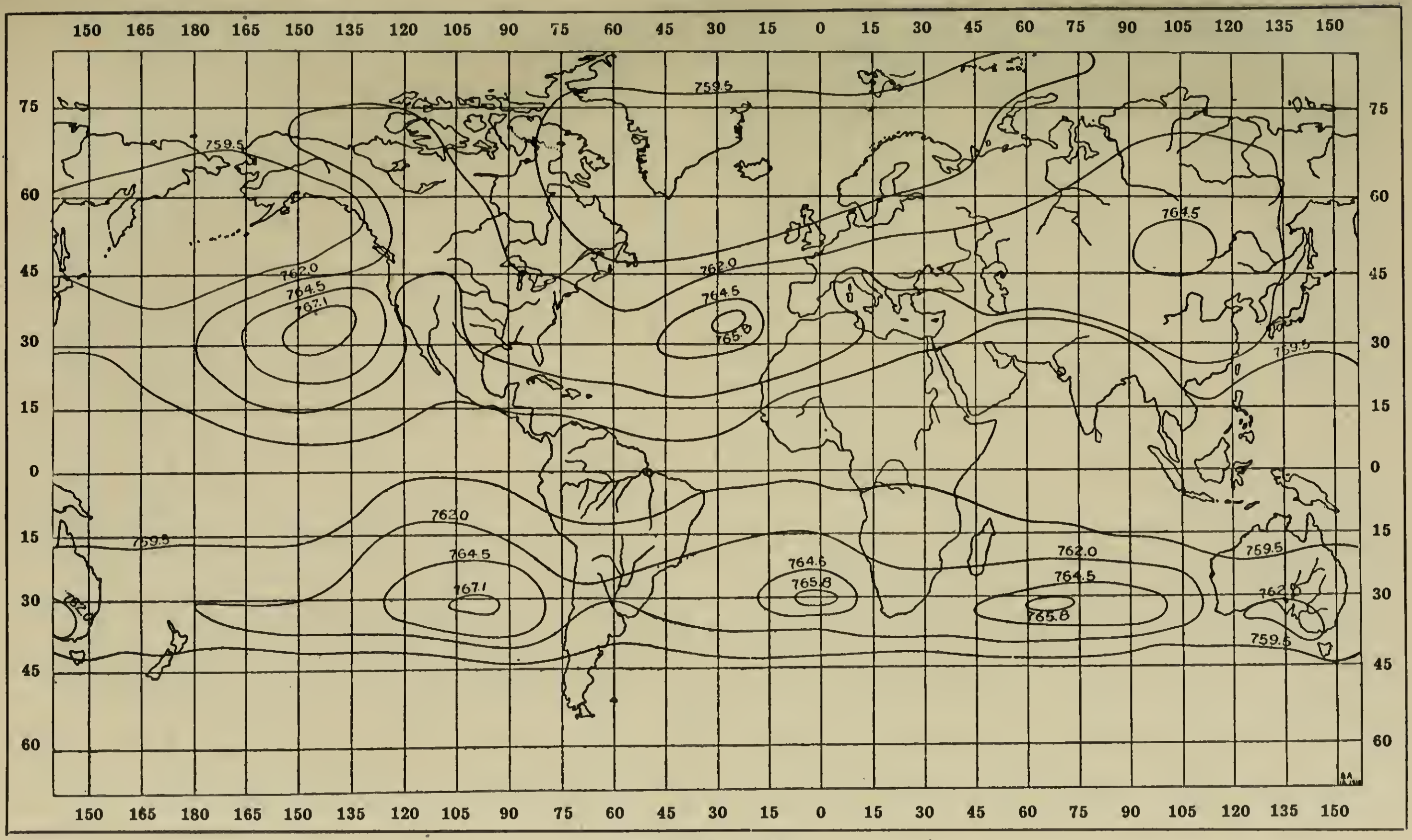
Given the isothermal condition of the upper atmosphere, it follows that the heated surface air can, under favorable circumstances, rise till, but only till, by expansion it has cooled down to that temperature (the temperature of the isothermal region) below which the radiation from the lower atmosphere will not allow it to fall.

The existence of an upper isothermal region and the vertical temperature gradient (Fig. 2) suggest rational explanations of a number of otherwise obscure meteorological phenomena,—why the clouds of a given region have a fairly well defined maximum elevation, why this elevation is greater in summer than in winter, why there are three levels, and only three, of maximum cloud formation, and the like,—but, though interesting, all these are secondary phenomena, and therefore a further discussion of them will be omitted.

PERMANENT OCEAN HIGHS.

Next after the above consideration of conditions that limit the vertical movements or convection of the atmosphere it may be convenient to examine some of the chief factors in the control

FIG. 5.



Annual average isobars.

of its horizontal circulation. Among the more important of these factors are the permanent ocean highs, of which there are five: two, as Fig. 5 shows, about 35° north of the equator, and three about 32° south of it. Two are on the Pacific Ocean, one west of southern California, the other off the coast of Chile; two on the Atlantic Ocean, near Morocco and southern Africa, respectively; and one on the Indian Ocean, about half way between Africa and Australia.

Obviously there must be a close relation between the positions and intensities of these ocean highs and the climates of adjacent regions, since they largely control the directions and velocities of the encircling winds, and therefore what it is that fixes their position and regulates their intensity is a meteorological question of fundamental importance.

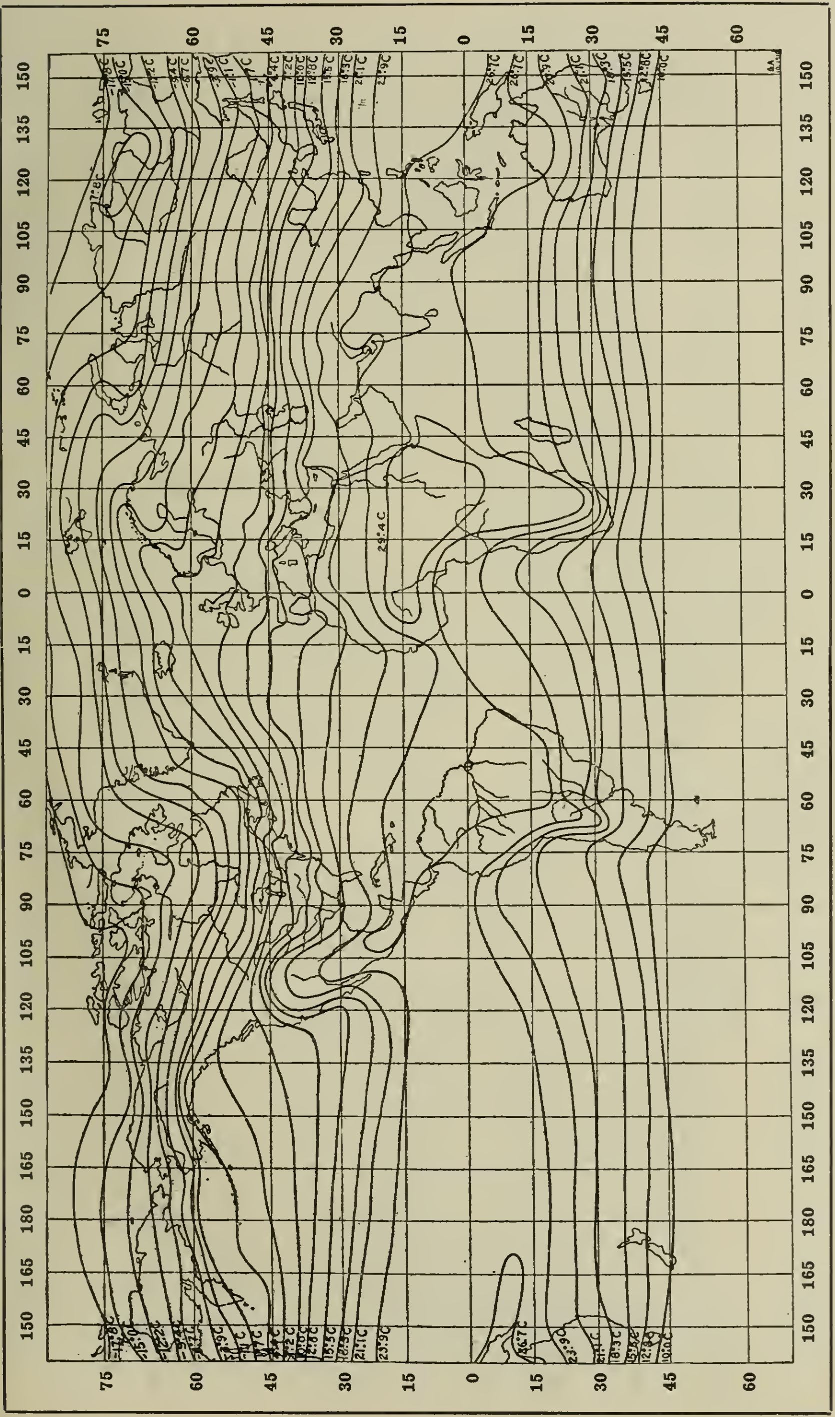
The difference in temperature between equatorial and polar regions causes a general planetary circulation of the atmosphere, the details of which are complicated beyond expression by the rotation of the earth, the distribution of land and water, irregularities in elevation, erratic distribution of clouds, and many other disturbing elements. But, in spite of this hopeless complexity of details, certain general features are obvious enough, just as the course of a river is clear despite its numerous turns and its countless eddies.

One of the most important of these general features, one caused by the rotation of the earth, is the prevalence of westerly winds along middle and higher latitudes. Another important feature, complementary to the one just mentioned, and due to the same cause, is the prevalence of easterly winds along and between the trade belts.

But as the bulge of the earth is adapted to the equilibrium of stationary objects, it follows that neither the westerly winds of middle latitudes nor the easterly winds of the equatorial regions can be in equilibrium on its surface. The former, through their increased centrifugal force, tend to climb up toward the equator, while the latter, because of the decrease in their centrifugal force, tend to slide down toward the poles. Hence along those belts that separate the prevailing west from the prevailing east winds, or about 30°–35° N. and S., there is a banking up of the atmosphere and a higher barometric pressure.

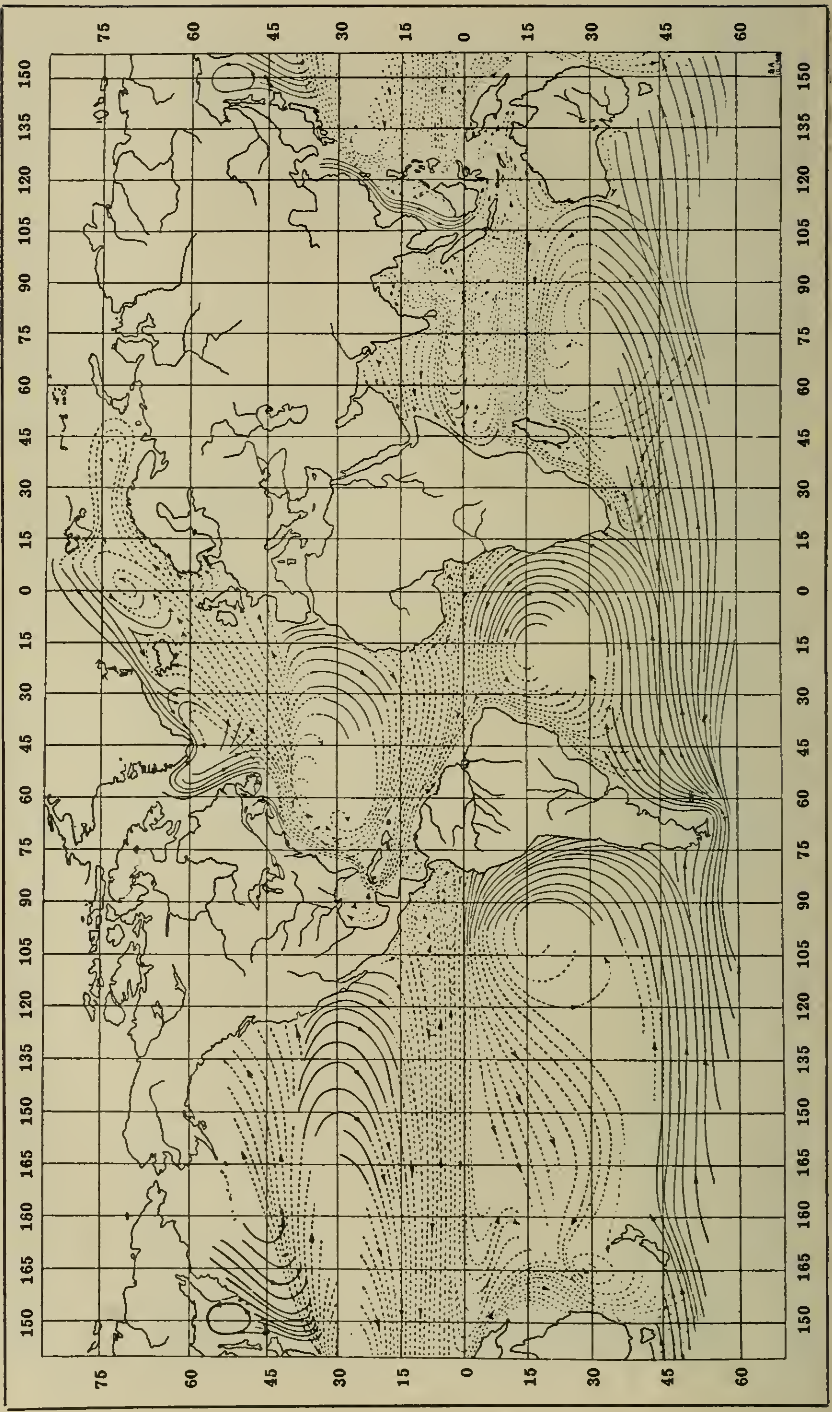
This, then, in a general way, is the accepted explanation

FIG. 6.



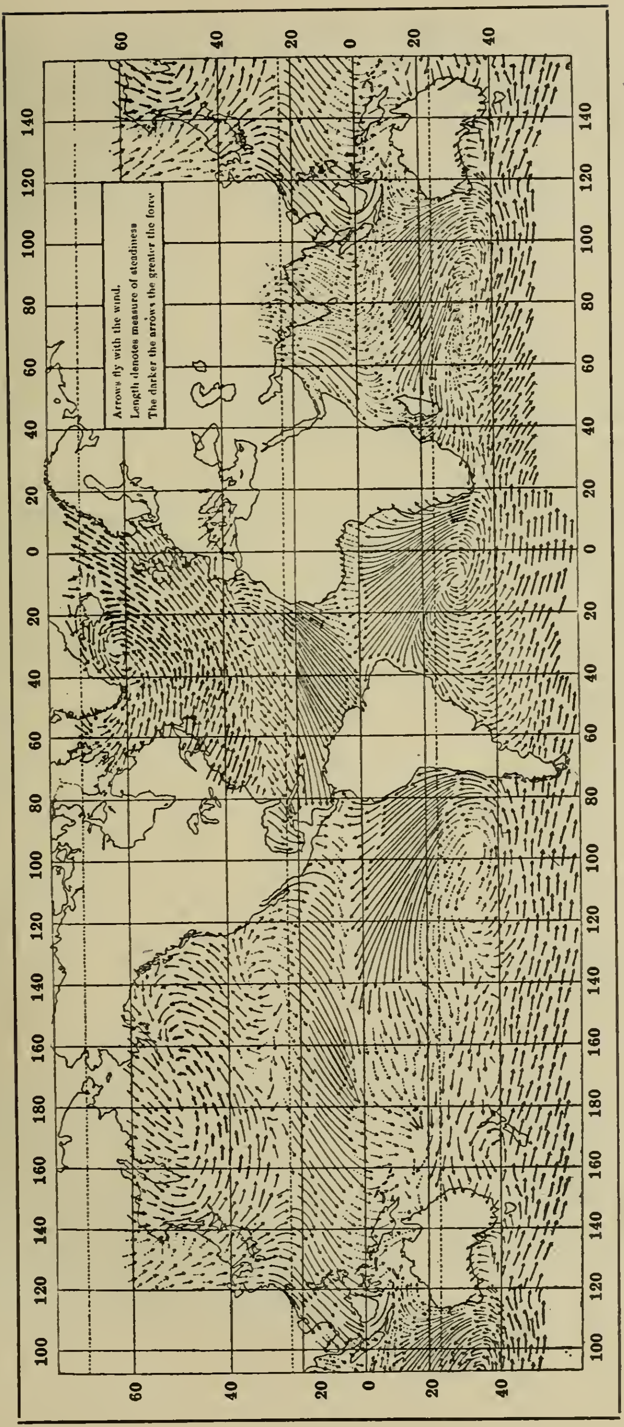
Annual average isotherms.

Fig. 7.



Ocean currents; full lines, cold; dotted, warm.

Fig. 8.


Arrows fly with the wind.
Length denotes measure of steadiness
The darker the arrows the greater the force

Ocean winds, January, February.

of the origin of the belts of high pressure, but it offers no hint as to why there should be special sections of these belts where the prevailing pressure is higher than elsewhere in their neighborhood in any direction. Of course, the belts are more or less broken up by the temperature and other irregularities of continents over which they pass, but this is not sufficient to create distinct centres of highs, nor to locate them where they actually occur.

By referring to Fig. 5 it will be seen that the regions of maximum pressure, as indicated by the isobars, occur at those places *along the belt of highs* where the temperature of the air is low for the given latitude, as shown in Fig. 6, or where the air isotherms are deflected equatorward. At these places, then, there are two causes of high pressure: (*a*) the mechanical pressure, as above explained, that produces the general belt of high pressure, and (*b*) a relatively low temperature, which leads to contraction of the superincumbent air column, and a resultant inflow of the upper atmosphere. The two causes operating together give local maxima of pressure, which, as Figs. 8 and 9 show, exert at least a partial control on the circulation of the atmosphere for great distances roundabout, and in large measure determine the weather and types of climate of a considerable portion of the earth.

But what, one naturally asks, is the cause of the persistent relatively low temperature of the air over the particular regions in question? This, too, is answerable, and the answer furnishes the real explanation of the origin of the fixed ocean highs.

Referring to Fig. 7, it will be seen that there are five different places, and only five, where a cold ocean current crosses a belt of high barometric pressure, and that every one of these is associated with a region of maximum atmospheric pressure. Neither is there a permanent ocean high at any region except where a cold current crosses a belt of high pressure.

It is the cold water, then, that cools the air and allows it to contract, and wherever this tendency to increase the pressure is joined with the mechanical effect to produce the *belts* of highs, there, and only there, as shown by Fig. 10, are found a maximum of pressure, and the centre of a more or less permanent anticyclone. As a matter of fact in each case, because of the reaction of the anticyclonic circulation, the highest pressure occurs a little to the west of the region of lowest temperature.

The ocean currents, in turn, are caused by winds, rotation of the earth, deflecting barriers, and a number of other contributing elements; hence there exists between all these phenomena a complex interrelation of cause and effect, of action and reaction, that cannot always be wholly disentangled. But this does not invalidate the sufficiency of the above explanation of the origin of ocean highs.

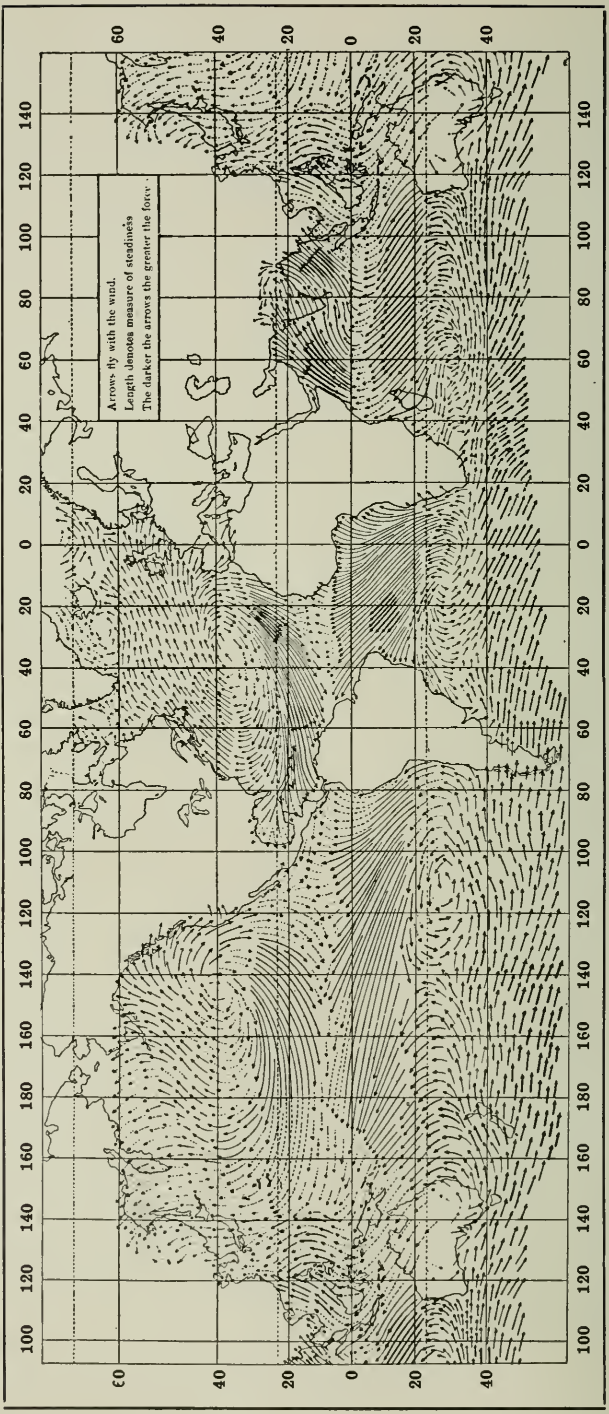
WIND STRUCTURE.

In addition to the phenomena of the general circulation of the atmosphere, a great deal of attention is now being given to the structure of air currents at different levels and under different conditions; partly because of its importance as a meteorological problem, but especially on account of its vital interest to aëronautics. Fortunately, too, while the details of air turbulence, like the turmoil of water rapids, are hopelessly beyond the power of theory fully to solve, the larger and relatively more important features give results in satisfactory agreement with rational theories, and are therefore predictable from certain known, or at least knowable, antecedent conditions.

General Wind Movement.—Obviously, every wind is caused by a pressure difference in the atmosphere along gravity equipotential surfaces. The fact that this difference, in turn, owes its origin almost wholly to temperature inequalities is for the present of no importance. For convenience, consider that one of these equipotential surfaces which coincides with the ocean surface. Now let a pressure difference be somehow established between a certain place and a neighboring region. At once the atmosphere begins to move from the region of higher toward the region of lower pressure, with an acceleration proportional to the pressure gradient, or ratio of pressure change to distance.

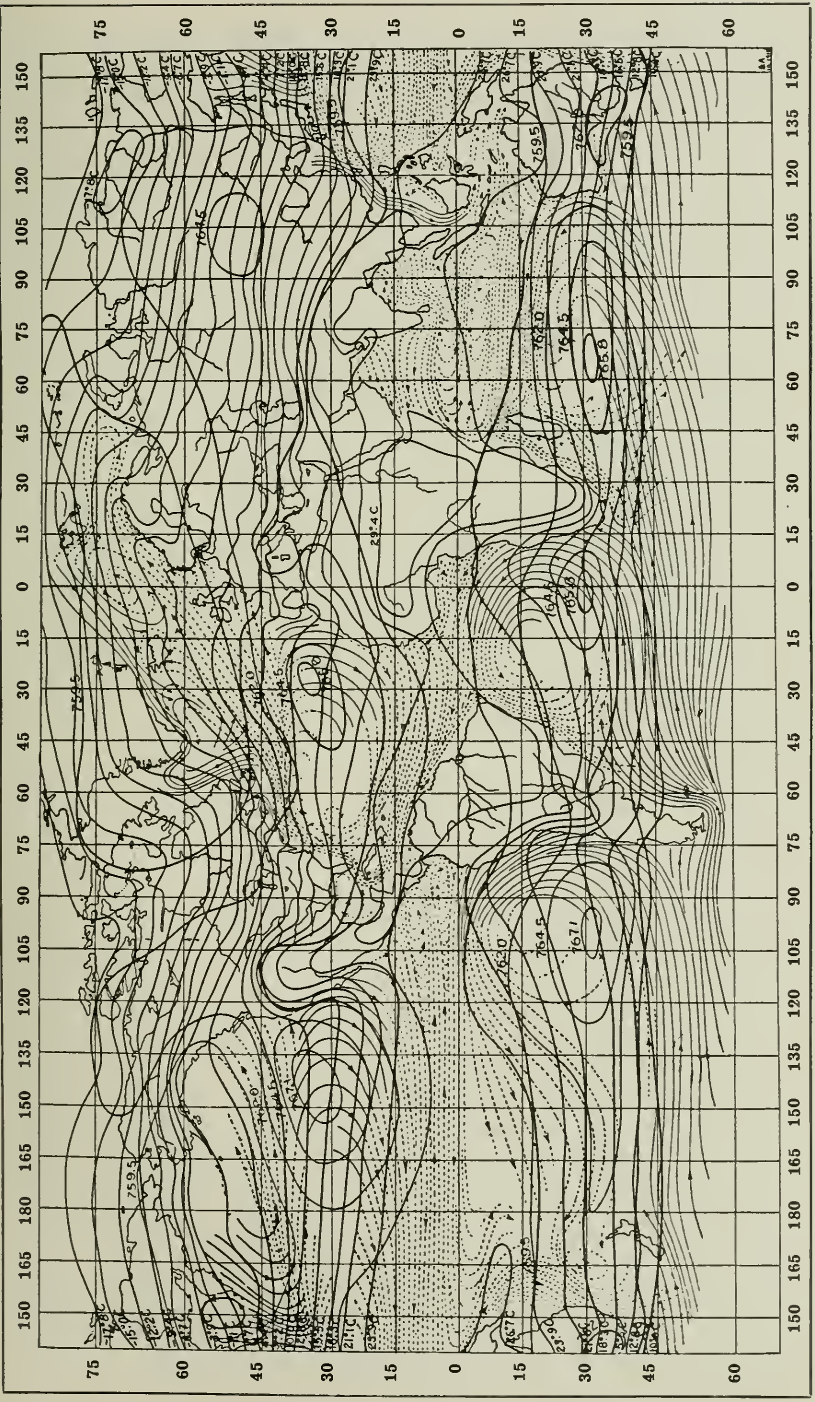
At first it might seem that the atmosphere would flow from the region of higher directly to the region of lower pressure, and thus quickly reëstablish a condition of pressure equilibrium. But this simple result never happens, because, as soon as the flow begins, new forces become immediately operative: one due to the rotation of the earth, another due to centrifugal action, and a third caused by friction and viscosity.

FIG. 9.


Arrows fly with the wind.
Length denotes measure of steadiness.
The darker the arrows the greater the force.
100
120
140
160
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
60
40
20
0
20
40

Ocean winds, July, August.

FIG. 10.



Superposition of ocean currents on annual average isotherms and isobars.

At a kilometre and more above the earth's surface frictional effects generally are negligible, and therefore for such altitudes we can write, as may be shown, the equation

$$g = \rho \left(2\omega v \sin \phi \pm \frac{v^2}{r} \cos \beta \right)$$

in which g is the pressure gradient, or the ratio of the pressure change to distance at right angles to the isobar passing through the place in question, ρ the density of the atmosphere, ω the angular velocity of the earth, v the velocity of the wind, r the radius of curvature of its path, β the angle between the plane of this path and the plane of the horizon, and ϕ the latitude. Further, the plus sign applies to cyclonic circulation, clockwise in the southern hemisphere and counter clockwise in the northern, and the negative sign to the reverse or anticyclonic circulation.

In this case (absence of friction) equilibrium is established not by a restoration of equal pressure, but by the production of a wind along the isobars of such velocity that the deflecting force shall be equal to the pressure gradient.

Except in the case of tornadoes, the second term in the parenthesis is small in comparison with the first. That is, the centrifugal force, except in extreme cases, is small in comparison with the deflective force due to the rotation of the earth. Hence, ordinarily we can write, as a close approximation,

$$v = \frac{g}{2\omega\rho \sin \phi}$$

Owing to friction of the atmosphere on the surface of the earth, and, in some measure, to its viscosity, the actual surface velocity of the wind is nearly always less than the calculated gradient velocity, and also more or less inclined to the direction of the isobar passing through the place in question; the inclination being toward the region of lowest pressure.

For a considerable elevation, both the gradient pressure and the density of the atmosphere decrease at about the same rate, and therefore the wind velocity commonly increases and its direction gradually changes, each at a nearly uniform rate, with increase of elevation, till at the height of 1200 metres the gradient velocity is approximately reached, and the direction becomes substantially parallel to the local isobar.

Hence the above gradient velocity equation is of special importance to aëronauts, in that it gives the velocity of the wind as well as its direction (along the isobar) that may be expected at even moderate altitudes.

As a matter of convenience to the aëronaut, it may be well to substitute numbers for symbols in the velocity equation, and to show how, by the aid of this equation, he may profitably use the daily weather map as an indicator of the winds to expect should he go aloft. In this numerical substitution the needs of the largest number of aëronauts will best be met by expressing the velocity in terms both of metres per second and of miles per hour.

Using the C. G. S. system of units, we have the equation:

$$\frac{\text{centimetres}}{\text{seconds}} = \frac{\text{change in dynes per square centimetre per centimetre horizontal distance at right angles to isobar}}{2\omega\rho \ \sin\ \phi}$$

To make the problem definite, let isobars be drawn for each millimetre difference in barometric pressure, and let the shortest distance between the isobars at the place where the gradient wind velocity is desired be 100 kilometres, and let the latitude of the place be 40°.

Now the density of mercury is approximately 13.6. Hence a column of mercury one millimetre high and one square centimetre in cross section weighs 1.36 grammes, or $980 \times 1.36 = 1332.8$ dynes. In the assumed case, therefore, of a difference in barometric reading of one millimetre per 100 kilometres the pressure gradient is $1332.8/10^7 = 13328 \times 10^{-8}$.

Further,

$$\omega = \frac{2\pi}{86400} = \frac{\text{the number of unit angles in a circumference}}{\text{the number of seconds in 24 hours.}}$$

$\rho = .0012$, the density of air under normal conditions.
Sin $40° = .64279$.

Hence,

$$2\omega\rho \sin 40° = 1122 \times 10^{-10}, \text{ about,}$$

and finally

$$v = 13328 \times 10^{-8}/1122 \times 10^{-10} = 1188 \frac{\text{centimetres}}{\text{second}}$$

or 11.88 metres per second.

Hence, along or near the parallel of 40° the gradient velocity, in metres per second, for any given time and place, is, to a first approximation,

$$12n/K$$

in which n is the difference in millimetres between the readings of the nearest isobars to the place in question, and K is the number of hundred kilometres between them.

The isobars on European weather maps commonly indicate pressure differences of 5 millimetres. Hence on these maps the gradient velocity in metres per second is, roughly,

$$60/K$$

On English, Canadian, and American weather maps an isobar is drawn for each tenth of an inch difference in barometric pressure, and in these countries wind velocities are generally expressed in terms of miles per hour. A little calculation, however, adapts the velocity equation to these maps, and shows that for latitude 40° the gradient velocity of the wind is approximately

$$19/M \text{ miles per hour}$$

where M is the number of hundred miles between the adjacent isobars.

These velocities, as already explained, are for latitude 40°, and doubtless therefore are sufficient for most cases, but the following table applies roughly to all regions:

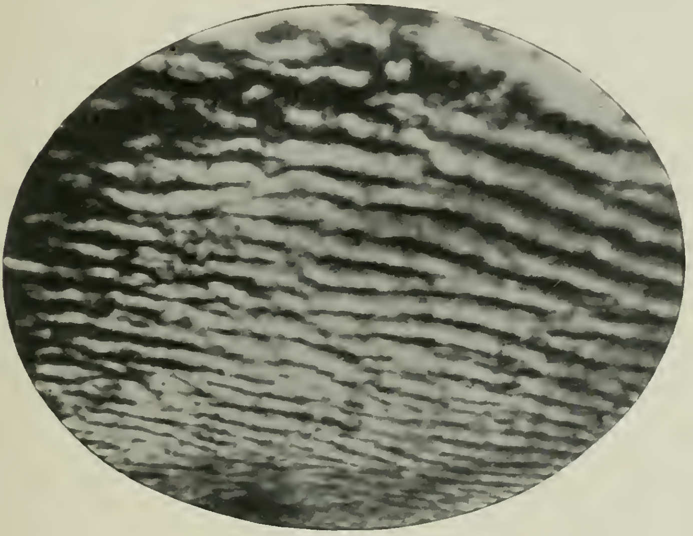
GRADIENT WIND VELOCITY.

Latitude.	Metres per second.	Miles per hour.
10°	44/K.	70/M.
20°	23/K.	36/M.
30°	15/K.	25/M.
40°	12/K.	19/M.
50°	10/K.	16/M.
60°	9/K.	14/M.
70°	8/K.	13/M.

For regions of higher latitudes than the trade wind belts, gradient velocities generally are reached when the wind is anywhere in the quadrant S.W.–N.W., and not infrequently there is but little change from this velocity through a considerable range of altitude. On the other hand, when the wind is in the quadrant S.E.–N.E., the full gradient velocity may not obtain at all, and, besides, after reaching a certain altitude the aëronaut may come first into nearly still air, and then into wind of almost any direction and velocity.

This brings us to the consideration of wind layers and their effect on an aëroplane. As first clearly explained by Helmholtz, two layers of air that abruptly differ in temperature or humidity, or both, as often happens, can glide the one over the other without rapid intermingling. Any such motion, however, sets up a series of regular interface billows, when the winds are in the same or opposite directions, and irregular, choppy waves when the winds are more or less crossed. Occasionally the cooler crests of aërial billows are rendered conspicuous by long parallel rows of clouds, as shown in Fig. 11, but as such a cloud formation requires a special degree of saturation, it follows that. ordinarily, air billows, having nothing to render them visible, must be far more numerous than recorded observations would indicate.

FIG. 11.



Clouds; alto-cumulus rolls.

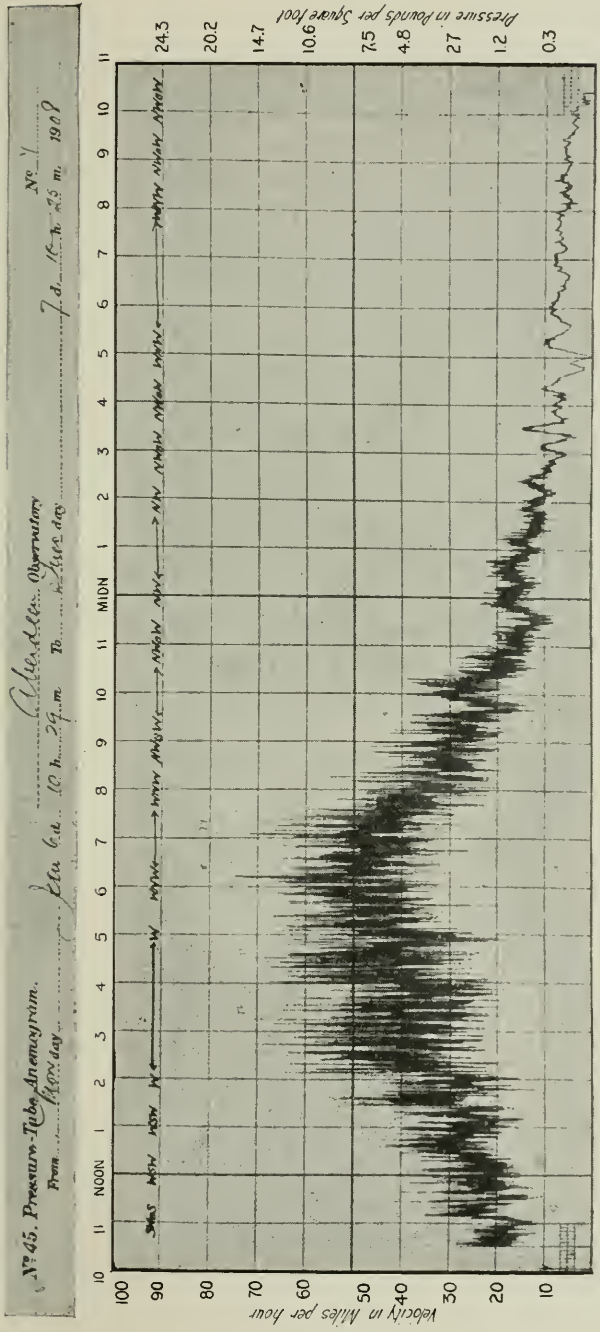
Air sheets of this nature usually occur at altitudes above those ordinarily frequented by aëronauts, but occasionally they are found well within flying levels, where they may be excessively dangerous. To illustrate, let the aëroplane be headed directly against the wind in an upper current, and let it pass to a lower current moving in the same direction and with the same velocity as the aëroplane. In this case the machine is in precisely the condition of one dropped in still air, and therefore, at least momentarily, is wholly without support or any power of guidance. If this condition should occur at a considerable altitude, a skilful operator, even though volplaning with all power shut off, might still be able to convert his rapid fall into a harmless glide, but his situation certainly would be one of great danger. Nor is the unusual condition here assumed—zero velocity of the machine with reference to the air—the only one that is dangerous. Since, with a given angle of inclination of wing to air,—or, to be technical, a given angle of attack,—the supporting force is approximately proportioned to the square of the velocity, it follows that any decrease in this velocity produces a much greater decrease in the support, and also in the power of control. Besides, wind sheets ordinarily do not flow parallel to each other, either in the same or opposite directions, but more or less across each other, and therefore, as a rule, the aëronaut in going from one such layer to the other has to contend with more than a disconcertingly abrupt change in the supporting force. That is to say, in addition to a partial loss of support, he usually has to contend with the turmoil of a choppy aërial sea, in which his equilibrium is by no means secure. Wind layers of the kind just discussed generally are easily detected by the use of small pilot balloons, and obviously should be carefully avoided by heavier than air machines.

Near the surface of the earth the wind is always in a turmoil, owing to friction and to disturbances caused by hills, bluffs, trees, houses, and numerous other obstacles. Indeed, the actual velocity of the wind at any given place near the earth's surface often varies from second to second by more than half of its average velocity, and the greater the average velocity, the greater, in approximately the same ratio, are the differences in the momentary velocities that rapidly succeed each other.

These facts are well illustrated by pressure tube traces, as shown by Fig. 12, copied from Report No. 9 of the British Advisory Committee for Aëronautics.

Similarly, two places, though separated by no more than fifty

FIG. 12.



Irregularities in the surface wind velocity as indicated by a pressure-tube anemometer.

feet, and that, too, in any direction whatsoever, while having, of course, substantially the same average wind velocities, often have radically different simultaneous velocities. Nor is this all; for near the surface of the earth even the wind direction suffers frequent and erratic momentary changes.

Now it is the momentary condition of the wind, its velocity and direction with reference to each part of his machine, that chiefly concerns the aëronaut; and, as he needs especially steady and uniform conditions, it is quite obvious that the windier it is the higher in general he must fly.

In addition to the horizontal flow of the atmosphere with its incident billows, where one layer glides over another, and surface turmoil, there are also other movements, and especially those due to vertical convection, whether mechanically forced or thermally induced. Thus as examples of the former, when the wind is at right angles in general to the trend of a mountain or range of mountains it is forced to flow up the windward and down the lee side, and the forced billow thus produced so acts upon the higher layers that atmospheric waves parallel to the mountain range extend, though with decreasing amplitudes, to very considerable elevations.

Temperature differences, as above implied, also cause vertical convections that greatly add to the complexity of atmospheric motions, but, fortunately for the aëronaut, the great majority of such movements are too slow seriously to disturb his equilibrium.

Under the influence of insolation, the surface of the earth, especially when it is barren, becomes heated often to many degrees above the average temperature. The soil in turn heats and expands the overlying atmosphere, which is then buoyed up by the adjacent colder and relatively heavy air. In this way currents of air, with an upward velocity sufficient to support soaring birds, are frequently obtained, but ordinarily neither they nor their necessary counterparts, the descending currents, are at all violent. Neither is there any violence in the atmosphere caused by evaporating, and therefore cooling and descending, clouds.

There is, however, a violence of vertical motion and a resulting turbulence in the midst of large cumulus clouds, as their forms and movements plainly show, to which no cautious aëronaut will ever expose himself, even if he should feel lightning proof, which he certainly would not be.

It will be worth while, since it is a mooted question, to consider here the probable cause of the violent motions in large cumulus clouds,—motions of quite a different order of magnitude, presumably, from those of any other portion of the atmosphere, since they are never exhibited by small clouds of any kind, nor met with elsewhere by either manned, sounding or pilot balloons.

Von Bezold [6] shows that sudden condensation from a state of supersaturation, and also sudden congelation following undercooling, would, as a result of the heat thus liberated, cause an equally sudden expansion of the atmosphere, and thereby turbulent motions analogous to those in large cumulus clouds. However, as von Bezold also points out, it is not evident how either the condensation or the freezing could suddenly take place throughout a cloud volume large enough to give the observed effects. Nor does it seem possible, with cloud particles already present, for any appreciable amount of supersaturation to occur. Hence the motions in question presumably have some other cause, and this we shall find in the difference between the actual temperature gradient of the surrounding atmosphere and the adiabatic temperature gradient of the saturated air within the cloud itself.

We will consider a warm summer afternoon, temperature 30° C., say, and assume the dew-point to be 15° C. Now, since the adiabatic decrease of temperature of nonsaturated air is about 1° C. per 100 metres change in elevation, it follows that, under the assumed conditions, vertical convection will cause condensation to begin at an elevation of approximately 1.5 kilometres. From this point, however, assuming the cloud particles to be carried up with the rising air, the rate of temperature decrease becomes much less—drops to about one-half the rate for non-saturated air. After a considerable further rise—half a kilometre, say—the rain drops formed by the additional condensation begin to drop out, and the amount of moisture condensed per degree fall of temperature grows rapidly less, and therefore, for both reasons, the temperature gradient again approaches the adiabatic gradient of dry air, or 1° C. per 100 metres elevation.

Obviously, then, for some distance above the level at which condensation begins to set free its latent heat, the temperature of the rising mass of moist air departs further and further from the temperature of the surrounding atmosphere at the same level, while the resulting buoyancy correspondingly increases.

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[6] *Sitzungsberichte Ber. Acad.*, 1892, pp. 279-309. (Translated by Abbe: Mechanics of the Earth's Atmosphere, Smithsonian Institution, 1910, pp. 249-279.)

In the lower atmosphere gradual and progressive convection prevents the occurrence of any great difference in temperature between the rising column and the adjacent air, and therefore the uprush in this region is never violent. But whenever the vertical movement of the air brings about a considerable condensation, it follows, as above explained, that there is likely to be an increase in the buoyancy, and hence a more or less rapid upward velocity of the central portion, together with a rolling and turbulent motion of the sides of the type so frequently shown by towering cumulus clouds. Obviously, too, the uprushing column of air must ascend more or less beyond its point of equilibrium, and then, because slightly undercooled, correspondingly drop back.

Fig. 13, based upon approximately average conditions, illustrates the points just explained. The elevation is in kilometres, and the temperature in degrees Centigrade.

AB is the approximate temperature gradient for non-saturated air, about 1° C. per 100 metres change in elevation. *GCKDEF* is the supposed temperature gradient before convection begins, or a decrease, in accordance with observations, of 6° C., approximately, per kilometre change of elevation, except near the surface, where the temperature decrease, before convection has begun, ordinarily is less rapid.

As convection sets in, the temperature decrease near the surface approximates the adiabatic gradient for dry air, and this condition extends gradually to greater altitudes till, in the assumed case, condensation begins at the point *C*, or where the temperature is 15° C. Here the temperature decrease, under the assumed conditions, suddenly changes from 10° C. per kilometre to rather less than half that amount, but increases slowly with decrease of temperature. At some point, as *L*, the temperature difference between the rising and the surrounding air is a maximum. At *D* the temperature of the column is the same as that of the surrounding air, but its momentum carries it on to some such higher point as *H*. Within the column, then, the temperature gradient is *ACLDHE*, while the temperature gradient of the surrounding air is given by *ACKDEF*.

The cause, therefore, of the violent uprush and turbulent condition within large cumulus clouds, presumably, is the temperature differences between the interior of the cloud itself and the surrounding atmosphere at the same levels, as indicated by their respective temperature gradients *CLD* and *CKD*.

ELECTRICITY OF THUNDER-STORMS.

The foregoing explanation of the violent uprush in the centre of large cumulus clouds is an important link in the modern theory of the origin of thunder-storm electricity, and therefore suggests that the introduction of that theory at this point would be both logical and in order, especially since it has but recently been developed.

Near the middle of the eighteenth century Franklin showed that the electricity of thunder-storms is an electrical phenomenon, but what its origin is he did not know. Indeed, in spite of numerous attempts to solve this mystery, it was not until quite recently that a consistent and experimentally supported hypothesis in regard to the origin of thunder-storm electricity was developed. The observations that suggested this hypothesis, and the experiments that seem to confirm it, both were made at Simla, India, by Dr. G. C. Simpson,[7] of the Indian Meteorological Department.

By means of a tipping bucket rain-gauge, an automatic record of the rate and time of rainfall was obtained, while at the same time a Benndorf self-registering electrometer marked the sign and potential of the charge acquired during each two-minute interval.

Thousands of such two-minute records were obtained during the monsoon seasons, April 15 to September 15, 1908 and 1909, from which Simpson concludes that:

(1) "The electricity brought down by the rain was sometimes positive and sometimes negative."

(2) "The total quantity of positive electricity brought down by the rain was 3.2 times greater than the total quantity of negative electricity."

(3) "The period during which positively charged rain fell was 2.5 times longer than the period during which negatively charged rain fell."

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[7] Part 8, vol. xx, Memoirs of the Indian Meteorological Department.

(4) "Treating charged rain as equivalent to a vertical current of electricity, the current densities were generally smaller than 4 x 10^{-15} amperes per square centimetre; but on a few occasions greater current densities, both positive and negative, were recorded."

(5) "Negative currents occurred less frequently than positive currents, and the greater the current density the greater the preponderance of the positive currents."

(6) "The charge carried by the rain was generally less than 6 electrostatic units per cubic centimetre of water, but larger charges were occasionally recorded, and in one exceptional storm (13th May, 1908) the negative charge exceeded 19 electrostatic units per cubic centimetre."

(7) "As stated in (3) above positive electricity was recorded more frequently than negative, but the excess was the less marked, the higher the charge on the rain."

(8) "With all rates of rainfall positively charged rain occurred more frequently than negatively charged rain, and the relative frequency of positively charged rain increased rapidly with increased rate of rainfall. With rainfall of less than about 1 millimetre in two minutes, positively charged rain occurred twice as often as negatively charged rain, while with greater intensities it occurred fourteen times as often."

(9) "When the rain was falling at a less rate than about .6 millimetre in two minutes, the charge per cubic centimetre of water decreased as the intensity of the rain increased."

(10) "With rainfall of greater intensity than about .6 millimetre in two minutes the positive charge carried per cubic centimetre of water was independent of the rate of rainfall; while the negative charge carried decreased as the rate of rainfall increased."

(11) "During periods of rainfall the potential gradient was more often negative than positive, but there were no clear indications of a relationship between the sign of the charge on the rain and the sign of the potential gradient."

(12) "The data do not suggest that negative electricity occurs more frequently during any particular period of storm than during any other."

Since the publication of Simpson's work, similar observations have been made at a number of other places, notably in France and Germany, and in all cases the results were in substantial agreement with those obtained in India, so that there can no longer be any doubt of the universality of the phenomena in question.

Simpson also devised a number of laboratory experiments imitative of thunder-storm conditions, and noted the electrical effects thus produced. Freezing, thawing, air friction and a few other things all gave negative results. Finally the breaking up of drops of distilled water by an air blast was tried, and at once positive results were obtained, showing that:

(1) "Breaking of drops of water is accompanied by the production of both positive and negative ions."

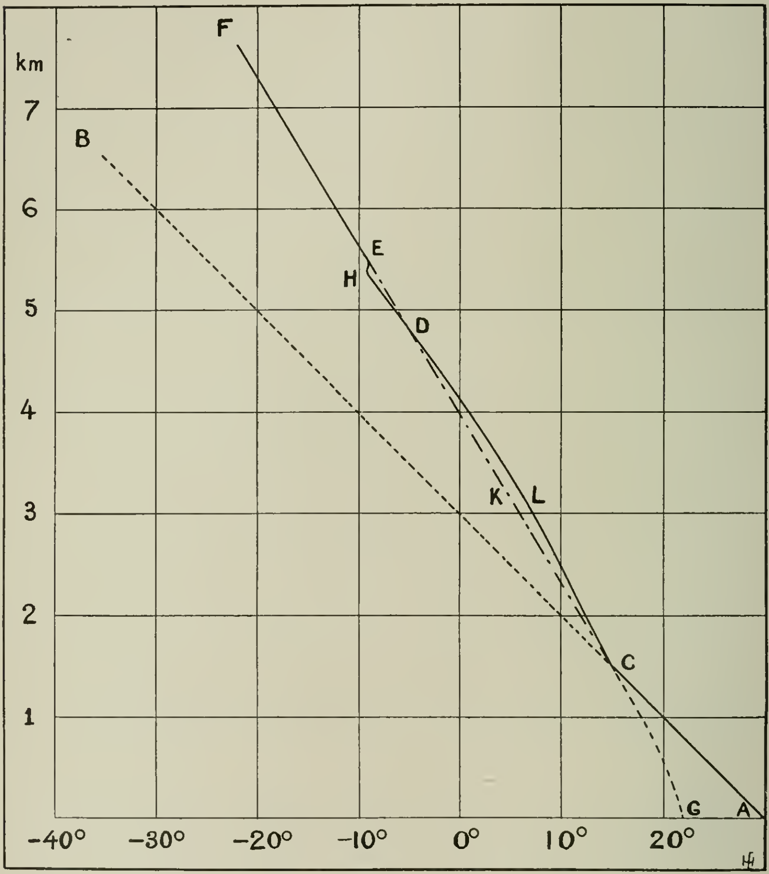
(2) "Three times as many negative ions as positive ions are released."

Now, as thunder-storms are usually, if not always, connected with large cumulus clouds, it follows, as explained in connection with Fig. 13, that a vigorous uprush of air is a necessary accompaniment of thunder-storms. Further, if the upward velocity of the air is as much as 8 metres per second—and it may easily exceed this amount—then no water drops, whatever their size, can fall through it. Those already small enough will be carried up, while the larger drops will be torn to bits, and the spray thus formed carried aloft.

It appears, then, that the strong upward currents of air within cumulus clouds necessarily must break up and thereby positively electrify the larger rain drops. These in turn doubtless unite again, possibly many times, only to be rebroken and still further positively charged. After a time the drops, of course, reach a place where the uprush of air is not sufficient to support them, and they fall as positively charged rain, while the negatively charged spray is blown aloft, from whence, after more or less coalescence into larger drops, it falls as negatively charged rain; though much of the negatively charged spray necessarily remains aloft, where it is slowly evaporated. Hence the bulk of the electricity brought down is positive, and hence, too, the heavier portions of the rain and the larger drops usually are positively charged, while the negative electricity is mainly confined to the lighter part of the storm, when the drops, as a rule, are comparatively small.

This, then, is the latest and apparently correct idea, as developed by Simpson, of the origin of the great amount of electricity in thunder-storms. If it had a weak point at all, as first set forth, it was in the assumption that such storms are always accompanied by a rapid uprush of air, sufficient to split up the larger rain drops; but Fig. 13 and its discussion seem to justify the assumption and thus fully to strengthen the one weak link in the logical chain.

FIG. 13.



Temperature gradients within and without cumulus clouds.

The above discussions might be greatly extended, and additional topics added to an almost indefinite extent, but this is impracticable, and, besides, it is hoped that enough has already been said to illustrate the claim made at the outset, to the effect that meteorology really is a branch of applied physics, full of the most interesting physical problems, both solved and unsolved.

THE BEHAVIOR OF ACID AMIDES IN THE SOIL.[1]

BY

SAMUEL L. JODIDI, B.S., Ph.D.

(CONTRIBUTION FROM THE CHEMICAL RESEARCH LABORATORY, SOILS SECTION, IOWA STATE COLLEGE AGRICULTURAL EXPERIMENT STATION.)

Of the well-known ten elements which have been recognized as essential for plant life, nitrogen plays a very prominent rôle. However, from the standpoint of plant food it is the available nitrogen—ammonia and nitrates—which is of special importance. Inasmuch as the nitrites and nitrates present in soils are chiefly the result of the nitrification of ammonia, it is at once evident that investigations concerning the formation of ammonia in soils will necessarily shed light upon the question of available nitrogen as a whole. Again, the production of ammonia in soils is closely associated with the chemical nature of the organic nitrogenous compounds occurring in soils.

Since it was shown by the writer [2] that acid extracts of soils are made up principally of monoamino acids, diamino acids, and ammonia—which latter is the result of the hydrolysis of acid amides contained in the protein molecule—it seems of considerable interest experimentally to demonstrate the behavior of the above compounds in the soil. Some of the changes to which amino acids are subjected in soils were reported in a previous publication. The latter contains, among other data, the results of ammonification of pure amino-acids like glycocoll, alanine, leucine, tyrosine, etc., on the one hand, as well as of asparagine—which is simultaneously an amino acid and acid amide—on the other. In this article the results of ammonification of acetamide and propionamide are presented.

The ammonia which is found on hydrolysis of proteins is commonly due to the presence in their molecule of the dicarboxylic acids asparagine and glutamine, which are contained in the protein molecule in the form of acid amide radicals. However, the behavior in the soil of acid amides other than those contained in the protein molecule is also of interest not only scientifically but for practical considerations as well. Aside from the fact that acid amides come into the soil with manures, it should be remembered that compound esters of organic acids not infrequently occur in nature,—for instance, in ethereous oils, wachses, fats, etc. Bearing in mind that esters easily combine with ammonia to form acid amides, it was deemed advisable to observe the behavior in the soil of acetamide and propionamide.

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[1] Communicated by the author.

[2] *Journ. Amer. Chem. Society,* vol. 32, 396 (1910); vol. 33, 1226 (1911); vol. 34, 94 (1912).

As is well known, the acid amides materially differ from amino-acids in their chemical behavior, which is due to their different chemical constitution: while in the former the NH_2 group is linked with the carbonyl group, it is in the latter directly united with the alkyl. In conformity with this different structure, the NH_2 group in the acid amides can be split off by various chemical means,—for instance, by treatment with boiling acid or with superheated steam,—whereas these means do not affect the amino-acids. However, our observations made with amino-acids and acid amides go to show that their behavior in the soil is not materially different, so far as ammonification is concerned. The above facts indicate that the deamination in the soil is due not to chemical processes but rather to bacterial activities.

Since factors like moisture, temperature, air, etc., have great influence on decomposition of organic matter, it was thought necessary to carry out the experiments under uniform conditions which fairly closely approach those existing in the soil, in order to be justified to draw more general conclusions from the comparable results thus secured. Accordingly, we kept the soils treated with acid amides always at room temperature; the moisture of the soils was throughout the experiments uniform, namely, about eighteen per cent.; the soils were always placed in covered tumblers or in beakers covered with Petri plates, in each case allowing sufficient circulation of air for maximal activity of the micro-organisms in question.

For the experiments reported in this investigation we used a soil composed of samples taken from twenty-two plots of the Iowa Agricultural Experiment Station field, which is situated on the Wisconsin drift. The soils in question were secured from the above plots in the fall of 1911. The plots having the size of one-tenth or one-twentieth of an acre were treated with various organic materials, such as manure, timothy, clover, peat, and grew a variety of crops, namely: corn, oats, timothy, clover, and cowpeas. The exact treatment of the plots, as well as their cropping up to 1909 inclusive, is recorded in form of a table in a former publication.[3]

The average composition of the composite soil used for the ammonification experiments was as follows:

Moisture	18.68 per cent.
Total nitrogen	0.296 per cent.
Ammoniacal nitrogen	1.63 per cent.
Nitric nitrogen	2.66 per cent.

The latter two figures are expressed in percentage of the total soil nitrogen. In connection with the ammonia determinations a few remarks may not be out of place here, bearing in mind that this paper is mainly based upon the ammonification experiments, and, further, that soils ordinarily contain but small amounts of ammonia, as was shown by our previous investigations,[4] as well as by those of others. For this reason it is quite essential to have an exact method for estimation of ammonia present or produced in soils. Especially was it deemed advisable to compare the mode of direct distillation of soils with magnesium oxide, which is most commonly in use, with the results obtainable according to Schlösing's method. The latter consists, as is known, in that to the soil mixed with double the amount of distilled water strong hydrochloric acid is added to distinctly acid reaction, whereupon more water is added to make up the liquid to a definite volume, which is commonly four times the amount of soil used. The whole is then well shaken, allowed to stand for several hours, whereupon an aliquot part of the filtrate is distilled with sodium hydroxide solution. The direct distillation of the soils with magnesium oxide was carried out in the usual way. In each case 50 grammes of soil were, with the aid of 100 or 150 c.c. of distilled water, quantitatively transferred to a copper flask of 600 or 1000 c.c. capacity, to which there were added some paraffin and about ten grammes of magnesium oxide previously reduced to cream with 100 c.c. of distilled water. The flask was now heated, the distillate being received in an Erlenmeyer flask containing $\frac{n}{10}$ H_2SO_4. The titration was performed against standard sodium hydroxide solution. The results obtained according to Schlösing's method are recorded in Table I, those secured by direct distillation of the soils with magnesium oxide are given in Table II.

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[3] Jodidi and Wells, Iowa Agr. Exp. Sta. Research Bull. No. 3, pp. 123, 124.

[4] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, vol. 32, 405 (1910); vol. 33, 1230 (1911); vol. 34, 95 (1912).

Table I.

Plots of 1911.	Wet soil used, grammes.	Corresponding oven-dried soil, grammes.	Nitrogen found.		
			Gramme.	Per cent. of oven-dried soil.	Per cent. of total soil nitrogen.
A......	100	84.25	0.00083	0.0010	0.273
B......	100	76.58	0.00091	0.0012	0.287
C......	100	77.20	0.00091	0.0012	0.309
D......	100	90.85	0.00176	0.0019	0.577
E......	100	76.60	0.00111	0.0014	0.541
F......	100	77.86	0.00225	0.0029	0.976
G......	100	79.50	0.00142	0.0018	0.643
H......	100	80.04	0.00101	0.0013	0.530
I.......	100	81.09	0.00232	0.0029	1.085
J.......	100	81.43	0.00204	0.0025	1.053
K......	100	80.95	0.00107	0.0013	0.580
L.......	100	80.58	0.00102	0.0013	0.465
M......	100	79.46	0.00119	0.0015	.....
N......	100	79.33	0.00204	0.0026	0.887
O......	100	84.79	0.00129	0.0015	0.474
P......	100	84.11	0.00119	0.0014	0.427
Q......	100	81.77	0.00041	0.0005	0.156
R......	100	83.12	0.00111	0.0013	0.429
S.......	100	84.20	0.00101	0.0012	0.467
T......	100	81.72	0.00260	0.0032	1.354
U......	100	81.76	0.00101	0.0012	.....
V......	100	81.84	0.00055	0.0007	0.242

In glancing over the Tables I and II we note that Schlösing's method gave considerably smaller figures, in the case of all the soils examined. This fact must be attributed to the presence in the soils of organic nitrogenous compounds which on direct distillation with magnesium oxide split off a part of their nitrogen in form of ammonia. Those compounds are, at least in part, of the acid amide and amino-acid type, as will be shown later.

In this paper, however, we decided to use the mode of direct distillation of the soils with magnesium oxide, because it is more convenient and requires less time. In addition, it should be borne in mind that by running blank analyses the above-mentioned error was eliminated as much as possible.

In connection with Table I mention may be made here of the fact that the data in question were secured by leaving the soils in contact with water and hydrochloric acid for a few hours only—anyway, not more than over night. When, however, the soils K, L, M, N, and O were treated with hydrochloric acid (10 c.c.) and distilled water (the total amount of liquid being 400 c.c.) and left in contact with the liquid for four days, the amounts of ammonia nitrogen found on distillation were as follows:

TABLE II.

Plots of 1911	Wet soil used, grammes.	Corresponding oven-dried soil, grammes.	Nitrogen found.		
			Gramme	Per cent. of oven-dried soil.	Per cent. of total soil nitrogen.
A......	50	42.13	0.00142	0.0034	0.94
B......	50	38.29	0.00131	0.0034	0.83
C......	50	38.60	0.00212	0.0055	1.44
D......	50	45.43	0.00153	0.0034	1.00
E......	50	38.30	0.00159	0.0042	1.55
F......	50	38.93	0.00212	0.0054	1.84
G......	50	39.75	0.00212	0.0053	1.92
H......	50	40.02	0.00212	0.0053	2.23
I.......	50	40.55	0.00170	0.0042	1.59
J.......	50	40.72	0.00208	0.0051	2.15
L......	50	40.29	0.00205	0.0051	1.87
M......	50	39.73	0.00191	0.0048	1.40
N......	50	39.67	0.00184	0.0046	1.72
P......	50	42.06	0.00254	0.0060	1.82
Q......	50	40.89	0.00166	0.0041	1.26
R......	50	41.56	0.00240	0.0058	1.86
S.......	50	42.10	0.00222	0.0053	2.05
T......	50	40.86	0.00212	0.0052	2.21
U......	50	40.88	0.00212	0.0052	1.63
V......	50	40.92	0.00142	0.0035	1.25

Plots of 1911.	Wet soil used, grammes.	Corresponding oven-dried soil, grammes.	Ammonia nitrogen found.		
			Gramme.	Per cent. of oven-dried soil.	Per cent. of total soil, nitrogen.
K......	100	80.95	0.00354	0.0044	1.918
L......	100	80.58	0.00288	0.0036	1.314
M......	100	79.46	0.00298	0.0038	.....
N......	100	79.33	0.00438	0.0055	1.904
O......	100	84.79	0.00489	0.0058	1.797

When we compare these figures with the results as summarized in Table I we can readily see that the percentage of ammonia found in the same soils increased as a consequence of the longer period during which they were in contact with the dilute hydrochloric acid. Inasmuch as the quantitative extraction of ammonia present as such in soils can be accomplished in a few hours, the only logical interpretation is the assumption that the soils examined contain nitrogenous compounds of the acid amide type which, subjected to the action of dilute hydrochloric acid, split off their nitrogen in the form of ammonia.

For the ammonification experiments with the acid amides it was deemed necessary to use a homogeneous, composite soil rather than the individual soils. The employment of the individual soils —which differ from each other so far as the percentages of moisture, total nitrogen, ammonia, nitric and organic nitrogen are concerned—would involve a considerable number of conditions rendering the experiments complicated and their interpretation difficult. Hence, the soils of the twenty-two plots were mixed as thoroughly as possible. We preferred to apply the field-wet soils instead of the air-dried ones, although it is quite hard, if at all possible, to obtain very good average samples of wet soils. This was done for the reason that soils, after they have been air-dried and then treated with water to make up their original moisture content, no longer possess the properties which the field-wet soils had, so far as, for instance, the biological processes of ammonification and nitrification are concerned.

SERIES I.

AMMONIFICATION OF ACETAMIDE IN THE SOIL.

The acetamide which was used for the following experiments was on purification subjected to analysis by the Kjeldahl method, which gave 23.62 per cent. nitrogen, while the formula CH_3CONH_2 requires 23.76 per cent. nitrogen.

Various amounts of acetamide were thoroughly mixed with weighed amounts of soil and kept in beakers covered with Petri dish covers at room temperature which ranged from 20° to 31° C. The odd soil numbers were distilled with magnesium oxide, the even numbers (their duplicates) with barium carbonate. The different reagents were used because it was found that acetamide, when mixed with soil and subjected without delay to distillation with magnesium oxide, split off a portion of its nitrogen in the form of ammonia. This is also true of propionamide. The amount of ammonia obtained by immediate distillation of acetamide and propionamide (plus soil), with either magnesium oxide or barium carbonate, was subtracted from the quantity of ammonia found on distillation of the acid amide-treated soils after they had undergone the process of ammonification.

That ammonia can fairly quantitatively be driven off by distillation of ammonia containing substances with barium carbonate, just as it can be done by distillation with magnesium oxide or sodium hydroxide, is evident from the following experiment: One gramme of ammonium chloride and ammonium sulphate respectively was dissolved in water, made up to 1000 c.c. and mixed well. Of these solutions 100 c.c. portions were distilled with either sodium hydroxide, magnesium oxide, or barium carbonate. The nitrogen obtained by distillation with magnesium oxide and barium carbonate was calculated to the nitrogen found by distillation with sodium hydroxide, the latter having been put down as 100 per cent. The data obtained are given in the following tabulation:

Substance applied.	Of solution taken, c.c.	$^n/_{10}H_2SO_4$ used, c.c.	Nitrogen found.	
			Gramme.	Per cent.
Ammonium chloride.	100	18.07	0.02537	100.00
Ammonium chloride.	100	18.10	0.02541	100.16
Ammonium chloride.	100	17.72	0.02487	98.03
Ammonium sulphate	100	14.77	0.02074	100.00
Ammonium sulphate	100	14.53	0.02040	98.36
Ammonium sulphate	100	14.20	0.01994	96.14

The results of the ammonification are presented in the following tables:

Soil number.	Amount of soil used for ammonification, grammes.	Moisture found.		Amount of substance added.
		Per cent.	Average.	
1	25	18.30		0.1 gr. acetamide
2	25	18.53	18.42	0.1 " "
3	50	18.48		0.1 " "
4	50	18.24	18.36	0.1 " "
5	100	18.40		0.1 " "
6	100	18.47	18.44	0.1 " "
7	150	18.32		0.1 " "
8	150	18.31	18.32	0.1 " "
9	25	18.51		0.2 " "
10	25	18.37	18.44	0.2 " "
11	50	18.41		0.2 " "
12	50	18.22	18.32	0.2 " "
13	100	18.42		0.2 " "
14	100	18.24	18.33	0.2 " "
15	150	18.37		0.2 " "
16	150	17.75	18.06	0.2 " "
17	25	18.14		0.3 " "
18	25	18.59	18.37	0.3 " "
19	50	18.42		0.3 " "
20	50	18.63	18.53	0.3 " "
21	100	18.55		0.3 " "
22	100	18.41	18.48	0.3 " "
23	150	18.32		0.3 " "
24	150	18.37	18.35	0.3 " "
25	25	18.26		0.5 " "
26	25	18.27	18.27	0.5 " "
27	50	18.47		0.5 " "
28	50	18.53	18.50	0.5 " "
29	100	18.36		0.5 " "
30	100	18.36	18.36	0.5 " "
31	150	18.25		0.5 " "
32	150	18.44	18.35	0.5 " "
33	25	18.01		1.0 " "
34	25	18.00	18.01	1.0 " "
35	50	18.01		1.0 " "
36	50	18.02	18.02	1.0 " "
37	100	18.22		1.0 " "
38	100	18.27	18.25	1.0 " "
39	150	18.06		1.0 " "
40	150	18.32	18.19	1.0 " "
41	25	18.42		2.0 " "
42	25	18.52	18.47	2.0 " "
43	50	18.26		2.0 " "
44	50	18.03	18.15	2.0 " "
45	100	18.11		2.0 " "
46	100	18.04	18.08	2.0 " "
47	150	18.44		2.0 " "
48	150	18.76	18.60	2.0 " "

Soil number.	Duration of ammonification.	Ammonia nitrogen found.		
		Milligrammes.	Average.	Per cent. of total nitrogen.
1	Nine days	18.81		
2	" "	18.79	18.80	79.59
3	" "	20.01		
4	" "	17.76	18.89	79.97
5	" "	17.95		
6	" "	14.63	16.29	68.97
7	" "	15.17		
8	" "	11.71	13.44	56.90
9	" "	31.67		
10	" "	35.48	33.58	71.08
11	" "	39.88		
12	" "	38.93	39.41	83.43
13	" "	37.49		
14	" "	32.66	35.08	74.26
15	" "	35.24		
16	" "	.....	35.24	74.60
17	Ten days	50.82		
18	" "	49.63	50.23	70.89
19	" "	58.64		
20	" "	58.29	58.47	82.51
21	" "	56.93		
22	" "	51.58	54.26	76.57
23	" "	52.83		
24	" "	.....	52.83	74.56
25	Twelve days	9.48		
26	" "	9.62	9.55	8.09
27	" "	86.35		
28	" "	90.39	88.37	74.83
29	" "	94.25		
30	" "	88.69	91.47	77.45
31	" "	90.44		
32	" "	.....	90.44	76.58
33	" "	12.99		
34	" "	7.93	10.46	4.43
35	" "	17.90		
36	" "	14.60	16.25	6.88
37	" "	190.15		
38	" "	175.78	182.97	77.46
39	" "	195.14		
40	" "	170.38	182.76	77.38
41	Thirteen days	5.04		
42	" "	5.38	5.21	1.10
43	" "	15.36		
44	" "	13.13	14.25	3.02
45	" "	16.16		
46	" "	......	16.16	3.42
47	" "	211.20		
48	" "	217.55	214.38	45.38

From the data just given we note that the agreement in the moisture content of the soil portions and their duplicates is very satisfactory. We further note that in the first 24 soils the production of ammonia is practically proportional to the quantity of acetamide added. However, in looking over the results in connection with the soils 25–48 we find some very striking figures. When the distillates obtained from the soil portions 25 and 26 were titrated and unusually small amounts of ammonia were found, it was first thought that loss in the operations must have occurred. The further titrations, however, have shown that what was true of the soils 25 and 26 held also good for the soil portions 33–36 and 41–46, in all of which the production of ammonia was materially reduced. In fact, in some cases it practically stopped altogether. A closer examination of the soils in question shows that the noticed phenomenon was the case when relatively large amounts of acetamide were added to comparatively small quantities of soil. Now, in the light of modern researches, decomposition of organic matter, like the process of ammonification, for instance, is the result of the activities of certain bacteria. Those activities can essentially be influenced by the presence of chemical substances. Thus, the bacteria can best thrive in a slightly alkaline medium. The presence of alkalies, acids, or soluble salts in excess reduces or stops bacterial activities altogether. In the particular case of ammonification the presence of ammonium salts in excess has the same effect. From the experiments of the acetamide series it follows that the presence of acid amides, like acetamide—and propionamide, as will be shown in the next series—influences the life functions of the bacteria in the same sense as do the acids, alkalies, or salts. So long as the quantity of acetamide added to the soil was in certain limits, the acetamide ammonified quite vigorously. When, however, the ratio of acetamide to soil increased, the ammonification of acetamide showed the tendency toward decreasing, and practically stopped altogether beyond a certain limit. The above facts can best be comprehended when we take into consideration the chemical nature of acid amides. They are neutral compounds and show neither basic nor acid properties, since the nature of the ammonia is neutralized by the acid residue. In other words, the acid amides can in a certain sense be considered as intramolecular salts, made up of an organic acid, on the one hand, and of ammonia, on the other. Hence, what is true of salts must also hold good for acid amides. When present in considerable quantities in the soil they must depress, or even stop, the activities of bacteria-producing ammonia. This, by the way, points to the necessity of distributing manures and commercial fertilizers in the soil as uniformly as possible.

Another interesting fact is that acid amides not occurring in the protein molecule, such as acetamide, ammonify in the soil as readily as asparagine, which is found in most of the proteins. Or, to put it in other words, the bacteria which are instrumental in bringing about the process of ammonification can utilize for their life functions acid amides not contained in the protein molecule, just as they are able to use the proteins themselves or those products of which the protein bodies are made up.

SERIES II.

AMMONIFICATION OF PROPIONAMIDE IN THE SOIL.

For the present series propionamide was used which on purification analyzed 19.00 per cent. nitrogen, as against 19.20 per cent. required by the formula $CH_3.CH_2.CO.NH_2$.

Fifty, seventy-five, one hundred, and one hundred and twenty-five gramme portions of soil were weighed out into tumblers and well mixed with various amounts of propionamide. The mixtures were kept in the covered tumblers at room temperature. The lowest temperature observed was 20° C., the highest 28°. The odd soil portions were distilled with magnesium oxide, their duplicates (the even numbers) with barium carbonate.

The results obtained are presented in the tables on the following pages.

While the agreement in the soil portions and their duplicates as to their moisture content is altogether satisfactory, the figures representing the amounts of ammonia produced are in some instances quite striking. We note that in the first 24 soil portions, with the exception of numbers 17 and 18, the intensity of ammonification was considerable. On the whole, the quantity of ammonia formed was here proportional to the quantity of pro-

Soil number.	Amount of soil used for ammonification, grammes	Moisture found.		Amount of substance added.
		Per cent	Average.	
1	50	18.29		0.1 gram propionamide
2	50	18.09	18.19	0.1 " "
3	75	18.22		0.1 " "
4	75	18.26	18.24	0.1 " "
5	100	18.40		0.1 " "
6	100	18.37	18.39	0.1 " "
7	125	18.19		0.1 " "
8	125	18.45	18.32	0.1 " "
9	50	18.50		0.2 " "
10	50	18.00	18.25	0.2 " "
11	75	18.74		0.2 " "
12	75	18.11	18.43	0.2 " "
13	100	18.80		0.2 " "
14	100	18.47	18.64	0.2 " "
15	125	18.26		0.2 " "
16	125	18.06	18.16	0.2 " "
17	50	19.03		0.3 " "
18	50	19.13	19.08	0.3 " "
19	75	18.14		0.3 " "
20	75	18.55	18.35	0.3 " "
21	100	18.85		0.3 " "
22	100	18.73	18.79	0.3 " "
23	125	18.41		0.3 " "
24	125	18.41	18.41	0.3 " "
25	50	18.77		0.5 " "
26	50	18.66	18.72	0.5 " "
27	75	18.46		0.5 " "
28	75	18.48	18.47	0.5 " "
29	100	18.44		0.5 " "
30	100	18.11	18.28	0.5 " "
31	125	18.71		0.5 " "
32	125	18.59	18.65	0.5 " "
33	50	18.30		0.75 " "
34	50	18.30	18.30	0.75 " "
35	75	18.74		0.75 " "
36	75	18.56	18.65	0.75 " "
37	100	18.24		0.75 " "
38	100	18.36	18.30	0.75 " "
39	125	18.34		0.75 " "
40	125	18.17	18.26	0.75 " "
41	50	18.46		1.0 " "
42	50	18.58	18.52	1.0 " "
43	75	18.56		1.0 " "
44	75	18.51	18.54	1.0 " "
45	100	18.77		1.0 " "
46	100	18.15	18.46	1.0 " "
47	125	18.38		1.0 " "
48	125	18.76	18.57	1.0 " "

pionamide added to the soil. However, an examination of the the soil portions 25–48 shows that the intensity of ammonification was here very much depressed. When we consider the figures

Soil number.	Duration of Ammonification.	Ammonia nitrogen found.		
		Milligrammes.	Average.	Per cent. of total nitrogen.
1	Eight days	13.44	13.81	72.68
2	" "	14.17		
3	" "	13.18	12.97	68.26
4	" "	12.75		
5	" "	13.09	12.44	65.47
6	" "	11.78		
7	" "	12.07	12.07	63.53
8	" "	.....		
9	" "	28.68	28.42	74.79
10	" "	28.15		
11	" "	28.61	28.47	74.92
12	" "	28.33		
13	" "	26.01	26.40	69.47
14	" "	26.79		
15	" "	26.53	26.42	69.53
16	" "	26.30		
17	Ten days	14.21	14.48	25.40
18	" "	14.75		
19	" "	42.68	42.83	75.14
20	" "	42.97		
21	" "	42.75	41.77	73.28
22	" "	40.79		
23	" "	40.46	40.00	70.18
24	" "	39.53		
25	" "	13.91	14.39	15.15
26	" "	14.86		
27	" "	20.68	20.47	21.55
28	" "	20.26		
29	" "	53.49	48.39	50.94
30	" "	43.29		
31	" "	71.19	69.63	73.29
32	" "	68.07		
33	" "	23.14	19.42	13.63
34	" "	15.70		
35	" "	26.54	24.28	17.04
36	" "	22.02		
37	" "	33.35	30.91	21.69
38	" "	28.47		
39	" "	45.07	39.25	27.54
40	" "	33.42		
41	Eleven days	19.07	16.86	8.87
42	" "	14.64		
43	" "	28.01	25.52	13.43
44	" "	23.03		
45	" "	32.23	30.47	16.04
46	" "	28.71		
47	" "	38.33	41.02	21.59
48	" "	43.71		

more closely we find that the depression of ammonification is congruent with the increase of the ratio of propionamide to soil. In other words, here, as in the case of acetamide, the intensity of ammonification reaches its maximum within certain limits beyond which it shows the tendency rapidly to decrease. The explanation for this phenomenon is again to be found in the chemical nature of propionamide, which represents, so to speak, an intramolecular salt. The latter, being easily soluble in water, forms in the soil a concentrated solution which depresses the activities of the ammonia-producing bacteria. On the other hand, this series confirms the data recorded in Series I, inasmuch as both propionamide and acetamide, not known to occur in the protein molecule, ammonify in the soil as readily as does asparagine, which has been found in most of the proteins investigated. It also confirms the observation already reported by the writer in another paper,[5] so far as the influence of the chemical constitution of a body on the intensity of its ammonification is concerned. Accordingly, propionamide approaches, although it does not fully reach, the acetamide in the intensity of ammonification, in agreement with the fact that propionamide is the next higher homologue of the acetamide, as illustrated by the following formulas:

$CH_3.CO.NH_2$	$CH_3.CH_2.CO.NH_2$
Acetamide	Propionamide

The above fact may, perhaps, be applicable in a more general way. In case of doubt as to the chemical constitution of a substance, its behavior in the soil, and especially the intensity of its ammonification, may give data throwing light upon the structure of its molecule.

The data secured permit of drawing the following conclusions:

Acetamide and propionamide readily undergo in the soil the process of ammonification.

As in the case of amino-acids,[6] the rate of transformation of the acid amide nitrogen into ammonia is greatly influenced by their chemical structure, so that acid amides of equal structure yield about the same proportion of ammonia.

The maximum percentages of ammoniacal nitrogen obtained from acetamide and propionamide were 83.43 and 75.14 respectively.

My thanks are due to Mr. E. H. Kellogg and R. Snyder for assistance in carrying out the routine work.

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[5] *Loc. cit.*

[6] *Loc. cit.*

THE ENGINEER IN THE BUILDING OF THE REPUBLIC.*

BY

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Who is he? What manner of man is this who has had a hand in the building of the Republic, and what has he done?

Who is he? Why, he is a man, every inch of him, a man to be reckoned with.

What manner of man is he? Physically, like King Saul of old, he may stand head and shoulders above the people; he may be a man of brawn and sinew or he may be frail and dapper, but in either case he will have the gift of continuance; he will set out to reach a goal, and, no matter what obstacles lie in his path, he will reach it.

He endures hardship like a good soldier; summer's heat and winter's cold try his endurance, but he endures. He traverses the rough places of the earth with an assured tread; his path is in the wilderness, and the solitary places know his footfall. If hunger overtakes him, he tightens his belt and still endures; thirst parches his tongue, but there are water springs, and he endures until their cooling draughts refresh him. The physical man is dominated by the intellectuality which dwells within him. Engineering is a science far-reaching and many-sided, dealing with the forces of Nature in all of their varied forms and combinations. This man of whom we are talking, perhaps—we may say assuredly—has not mastered this science in all of its branches, but he has chosen the division of that science to which he will devote his energies, physical and mental, and *that* he knows. He may have acquired that knowledge within college walls, and his alma mater may be dear to him, or he may have acquired what he knows in the hard school of experience, ending up days of toil with nights of study that he may know the reason for the things he has been doing or be ready to meet the problems that he knows lie ahead of him. He has more or less of the constructive instinct. He is a dreamer who can shut his eyes and see the thing he means to create take outline and form upon the trestle-board of his imagination. Or he maps in relief the territory over which he has tramped and selects upon the wrinkled face of Nature those furrows through which he will carry his roadway, excavate his canal, or across which he will build his dam.

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* Presented at the stated meeting of the Institute held Wednesday, December 18, 1912.

We have looked him over physically and mentally, but we cannot pass on to his work without a glance at his moral equipment. Honor lies at the base of the character of the engineer worthy of the name, and an honesty which is proof against the wiles of the devil or of fellow-man. We have now had an introduction to the man who has been doing things for the Republic. Let us see what he has been doing.

Less than a month ago I loitered beside a small land-locked harbor in one of our Chicago parks, and in that safe refuge there were three tiny ships of quaint design. It was a gala day, and these ships were bright with fluttering multi-colored flags, but dominating all was the flag that carries forty-eight stars upon a field of blue, from which thirteen united stripes swelled out upon the gentle breeze. Those ships had names that carried memory back over 420 years of American history, the *Pinta,* the *Nina,* and the *Santa Maria,* replicas of the three tiny craft that brought the first adventurous explorers from Spain to the New World; men whose courage and whose faith canonize them among the immortals. They found a wilderness world where the savage waged a never-ending strife with the wild beast. Years rolled by, and the men of England and the men of France followed in the wake of the men of Spain and laid claim to the new land, and the land and the savage and the wild beasts fought against the invaders. For a time inhospitable shores and savages and wild beasts prevailed against the white skins from over the sea, but the avarice of the white man with such a prize in view proved indomitable, and the lodgments along the St. Lawrence, the north Atlantic coast, the bays of Virginia, the coast of the Carolinas, Georgia, and Florida, and on the Mississippi were abiding, and the fate of the red man was irrevocably settled. He was to be despoiled of his lands; his hunting grounds were to become the arable lands of the whites; his herds of bison were to be slaughtered for the value of their pelts or even for the wanton sport of the whites; his tribes must retire as civilization advanced, and at last, hemmed in between this advance from both coasts, " 'minished and brought low," their remnants were to become the wards and the pensioners of the all-conquering whites. But this was the outcome of long years of struggle, not the result of sudden and decisive combat.

In this new land the waterways were the highways, for the forests were trackless, the streams unbridged, and the prairies were like uncharted seas. The settlements were along the bays and rivers, and there the cities grew. I was once a guest at a Washington Birthday dinner. One of the speakers was a railroad magnate to whom the topic assigned was " The Transportation Facilities of 1776." He arose and announced his topic and said, " It is one easily disposed of, there were none," but, nevertheless, he gave a very interesting talk upon this topic. But it is about time to make some showing for the engineer. May we not claim as one of us the man who began his career as a surveyor, locating by metes and bounds the princely estate of Thomas (Lord) Fairfax, the man who served with Braddock and saved the remnant of that ill-fated commander's army, the man who was the forefront and tower of strength of the American Revolution which made him the Father of his Country? The " Father of his Country," having fought for its liberties and won them, had all of a father's care for the nation that was born to him. None knew better than he the vastness and the inherent wealth of the land which they possessed, and none knew better than he what was needed to make that land what he saw it in his visions of the future. He recognized transportation as the foremost factor in the development of the new land. He planned highways and canals to meet the needs of transportation. The first canal project in the new land, of which history tells us, was the James River and Kanawha Canal, the first conception of which dates back to 1716 and is accredited to Governor Spotswood. But the first active steps directed to the realization of this project were taken by Washington, " who saw from his backwoods days the necessity of joining the eastern seaboard to the trans-Alleghanian territory by lines of communication." " He personally explored the James River route in 1784, and induced the Legislature of Virginia, on the 5th of January, 1785, to pass an act for the improvement of the James." Under this act the James River Company was organized on the 25th of January, 1785, with Washington as president. But time went by and Washington had rested for long years in his sarcophagus at Mount Vernon before a boat passed through that canal. His name is more intimately connected with the Chesapeake and Ohio Canal, which, as designed by him, was to connect the Chesapeake and ocean navigation by way of the Potomac with that of the Ohio by portages and high roads from Cumberland, at the foot of the Alleghanies. The route chosen by him from the head of navigation on the Potomac at or near Georgetown as far as Harper's Ferry was on the Virginia side of the river; after an expenditure of about three-quarters of a million dollars, this location was abandoned and the canal was built on the Maryland side, and it is one of the few early canals still in operation.

In 1790, Washington, as the head of a commission of three, acting under authority of Congress, selected the site of the capital of the young nation. *He* called it the Federal City. "Major l'Enfant, a French engineer serving in the Continental Army, was employed to superintend the laying out of the city, following plans outlined by Washington, derived, it is believed, from the outlines of Versailles, France." We cannot escape from the belief that Washington, born soldier, was also a born engineer. Canals and highways called forth the first efforts of the engineers of the new land. Their most conspicuous work was and is the Erie Canal, connecting Lake Erie with the Hudson River. Ground was broken for this canal July 4, 1817, and the original project was completed October 25, 1828. Its length was 363 miles. The drop from Lake Erie to the Hudson at Albany was 675½ feet, and the descent was accomplished by eighty-three lift locks. The immediate result of this waterway on commerce was to reduce the cost of freight from Buffalo to New York from $100 to $10 and later to $3 per ton. The report of the Engineer and Surveyor of the State of New York for 1905 gives brief sketches of the canals of this country, that are of much interest and great historic value. He schedules one hundred and forty canal projects in the United States, sixty-one of which have been abandoned. They were built to meet the needs of a young country and its infant industries; the country has aged and the industries become giants too big for the cradles of their young lives. Canals that were built to accommodate large craft are used to-day as freely as were the little ones of the long ago. The canals that connect the Great Lakes have a commerce to-day that is a world wonder, and the country is awakening to the need of wide, deep, and safe waterways; not as rivals to railroads, but as helpers to meet the growing demand for means of transportation, and for cheaper transportation. Under the direction of the engineers, the little Erie Canal is being enlarged and rebuilt so that the limitation to the craft navigating it will not be two hundred tons per boat, but one thousand tons.

Then there is the call for coastal canals along the Atlantic seaboard; and for the Lakes to the Gulf Deep Waterway, of which the first link, the Chicago Sanitary and Ship Canal, was completed thirteen years ago. But the engineer as a canal builder reaches the zenith of his endeavor in the construction of the Panama Canal. Where the French engineer failed, the American engineer is triumphing over all obstacles, and another summer will see ships floating upon a new lake whose surface will be eighty-five feet above the level of the sea and under whose waters 164 square miles of jungle and tropic vegetation will lie submerged. This lake is reached by a marine stairway, each step of which has a rise of 28⅓ feet and a usable tread of 1000 feet, 110 feet wide. This lake is supplied by the waters of the rivers Chagres, Gatuncillo, the Rio Trinidad, and lesser streams. The dam behind which these waters are accumulated is an earth structure about 7000 feet in length. It is 300 feet thick at the water line, and its greatest thickness at the base is about 1800 feet. It rises to an elevation of 115 feet above sea level. The regulating works which control the outflow are located about midway of the length of the dam, and the flight of locks which I have spoken of as a marine stairway is located at the east end of the dam. These locks are twin structures. The usable length is 1000 feet, the inside width 110 feet, and the navigable depth over mitre sills 40 feet. The volume of concrete in these six locks is 2,085,000 cubic yards. When I visited this work in February, 1909—with the then President-elect, Mr. Taft—the foundations for these locks were being tested. I was there in February of the present year, and in the interval between my visits 1,900,000 cubic yards of the total volume had been laid.

The lowest point in the divide through which the channel of the canal passes was originally 333 feet above mean sea level; the bottom of the canal, now nearly completed, will be forty feet above sea level; hence the cut in the lowest summit depression will be 293 feet, with a bottom width of 300 feet. The excavation from this cut is estimated as 93,882,000 cubic yards. The passage from Gatun Lake to the Pacific is through the Culebra Cut to the Pedro Miguel (twin) lock. The drop from this lock to the pool below is thirty feet, and the distance to the Miraflores locks is 1½ miles. There the drop of fifty feet to ocean level is accomplished by two locks (these locks are also in pairs). The building of the Pedro Miguel locks required 837,400 cubic yards, and the Miraflores locks 1,362,000 cubic yards of concrete. Simply to tabulate the volume of excavation and the cubiture of masonry, the depth and width of channels is a very tame and inadequate way of conveying an idea of the Panama Canal, which is a fitting theme for an epic in the poetry of great deeds. Its building is indeed one of those victories of peace more glorious than war, and the engineer has fought and won that battle for the Republic.

The little canals of the past were common carriers of no mean importance, for they helped to develop the country before railroads had entered in to possess the land, and the engineer built them.

But in the early days of the nineteenth century another sphere of usefulness demanded the skill, the courage, the genius, and the perseverance of the engineer. A new mechanical species appeared upon the earth which was destined to revolutionize transportation. The genus locomotive rolled over the world's horizon into the vision of mankind; a tiny thing at first, crude in its design and imperfect in its workmanship, but destined to increase and multiply and replenish the earth until its family in the United States numbered 58,947 in 1910; and as each decade passed, it grew in stature and in strength under the fostering care of the mechanical engineer. It is a far cry from Hedley's Puffing Billy of 1813 or Peter Cooper's Tom Thumb (1830) of 1½ horsepower to the Santa Fe Mallet freight locomotive, which is 120 feet 7 inches long, weighs 308 tons without the tender, and has a drawbar pull of 111,000 pounds, but it tells the story of locomotive development almost at a glance. This is the work of the mechanical engineer, and the railroad engineer and the bridge engineer has had to provide the road-bed, tracks, and bridges upon which these iron monsters can travel with safety and speed. The response has always been equal to the demand. In 1833 the longest railroad in the world was from Charleston, S. C., to Hamburg, in that State, 135 miles. The latest statistics to which I have had access give the railroad mileage in the United States at the end of 1910 as 240,830.75 miles single main track, 21,658.74 miles of second track, 2206 miles of third track, 1488.78 miles of fourth track, and 85,581.93 miles of sidings and yard tracks, or a total of 351,766.59 miles. We were going some in those seventy-seven years. This was the condition of two years ago, but the statistics of two years back are stale and almost unprofitable in this prolific age of ours. Well, who has done all of this? Our friend, the engineer, with becoming modesty admits that he is the man.

In 1860 Arkansas had but 38 miles of railroad, California 23 miles; and in the areas now known as Colorado, Idaho, Kansas, Minnesota, Montana, Nebraska, Nevada, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, Wyoming, Arizona, and New Mexico there were no railroads, and in Texas there were but 307 miles of railroad. George H. Daniels, in his paper, " The Railroad's Part " (in " The Making of America "), says: " Forty years ago the Prime Minister of Japan, in answer to the question, ' How can we introduce civilization into the interior of Japan? ' took a map and, drawing lines on either side of the range of mountains which extends for some distance through the centre of the Island Kingdom, said, ' Build railroads here and civilization will follow.' " Was it not true? Have we not seen that truth written many times across our continent? The occupation of the territory west of the Mississippi was a slow process. The city of St. Louis got its first railroad, the Missouri Pacific, in 1854. To-day it is one of the great railroad centres. The first notable movement of settlers to the west of the Mississippi was that of the Mormons in 1848, when persecution drove them from Illinois to a far country where they hoped to be let alone. The first transcontinental road to be commenced was the Missouri Pacific, which was arrested in its progress by the "War between the States." The first sod for the Central Pacific was turned on the 23d of February, 1863. Work was commenced on the Union Pacific, November 12, 1865. Fourteen years, or till July, 1876, was the limit of time allowed by the charter for the completion of the enterprise, but the eastern and western sections met and the last spike was driven at the station of Promontory on the 10th of May, 1869 (see James Douglas's paper, "American Transcontinental Lines," in "The Making of America," vol. iv, page 275).

It was my good fortune to listen to an address given by General Granville Dodge at the annual meeting of the Western Society of Engineers, January 5, 1909. He was chief engineer of the Union Pacific during its construction period, and a part of his absorbingly interesting talk related to the building of that road. It was a story of intense interest, dealing with hardship, exposure to the dangers of Indian onslaught, unremitting labor under high pressure, and a memorable victory over all difficulties. Speaking of the backers of the road, he said: "They spent many millions for speed, and constructed a road two thousand miles long in three years. The line crossed the Rocky Mountains at an elevation of 8235 feet. From May, 1868, to May, 1869, we built 555 miles of main line and over 180 miles of side and temporary tracks." In 1870, so he told us, this veteran of the Civil War and time-tried engineer undertook the building of the Southern Pacific Railroad, which he completed in 1883. He said: "It is a singular fact that the same engineers and the same foremen who joined the tracks at Promontory Point in 1869 met on the plains of Sierra Blanco, Texas, in 1883 and joined the tracks which connected the second continental line across the country, but under entirely different circumstances. There were no bands, no crowds, no speeches, and no champagne."

The stories of the Northern Pacific, the Denver & Rio Grande, the Atchison, Topeka & Santa Fe, the Northwestern, the Rock Island, the C., B. & Q., and the Milwaukee & St. Paul, with all of their offshoots and feeders, if told without embellishment, would rival in interest the most fascinating romance. These railroads the engineer has built, and made the wildernesses habitations for man, and it is no mere figure of speech to say that he has added to the Union all of the States west of the Mississippi, except Missouri, Arkansas, Iowa, Kansas, Minnesota, Texas, and California. He has done it.

Now we know about the 240,830 miles of main line that he has built, and we know that there were lots of bridges required for that length of line. Thomas Curtis Clark, in his paper on "Bridge Building" (see "The Making of America," vol. iv, page 395), tells us that "it has been estimated that there is one metallic bridge for every three miles of railway." Applying this rule to our single main track, we will have 80,276 metallic structures as the contribution of our bridge engineer to the building of our railroads. But he has not confined himself to railroads, and he has made wonderful strides in the development of his art since Howe was told that a train had passed safely over one of his bridges after the bottom chord had been burned nearly in two, and he explained it by saying "it was the principle that held it up." Wonderful structures span our rivers, our gorges, and carry traffic above our city streets. Captain Eads built the first steel arched bridge, and it stands to-day after a lapse of thirty-eight years, a thing of beauty and of strength, spanning the Mississippi and connecting St. Louis with its little sister city on the Illinois shore. To schedule the notable bridges of our own United States with the briefest description of each would expand this paper to most unreasonable length. Here in Philadelphia you have some beautiful examples of the bridge builder's ability to design and construct. In your neighbor city New York they boast proudly and justifiably of their first East River Bridge, built by Roebling, completed in 1883, with its span of 1595½ feet (still the largest suspension span in the world), which is crossed by more people than any other bridge in the country; their Williamsburg Bridge and their Blackwell's Island Bridge. We have notable structures widely scattered throughout our land, mostly metallic; but two masonry structures deserve special mention. The four-track arched bridge of the Pennsylvania Railroad crossing the Susquehanna River at Rockville, Pa., is a monumental structure, consisting of forty-eight segmental arches of seventy feet span, is one of these; and Flagler's Florida East Coast Railroad through the sea is another. It is a matter of pride with us that our engineer builds bridges so well and so economically that he is a successful competitor with Old World fellow-craftsmen for structures on the Dark Continent and on the islands of the sea.

He builds dams, too, the highest, the strongest, and the most useful dams in the world. He builds them to conserve flood waters that would otherwise rush onward to the sea and mingle their wasted sweetness with the brine. These dams create great reservoirs, the outflow from which is used to irrigate lands, parched with immemorial thirst, and cause the grateful soil to "bring forth seed for the sower and bread for the eater." What he has done since the reclamation act of 1902 gave him his commission is concisely told in a statement sent me by Mr. Blanchard, statistician of the Department of the Interior:

"In the ten years of its work the service has built 7300 miles of canal. Placed end to end these canals would reach from New York to San Francisco and back. Several of these canals carry whole rivers.

"It has excavated 21 miles of tunnels.

"Its excavations of rock and earth amount to the enormous total of 93,000,000 cubic yards.

"Its roads have a total length of 626 miles; telephones, 2094 miles; levees, 70 miles.

"It has purchased 1,051,000 barrels of cement, and has manufactured in its own mill 340,000 barrels. As a result of its work, water is available for 1,159,234 acres on 13,000 farms.

"The gross value of crops produced on the lands irrigated by the Government projects in 1912 was estimated at $20,000,000. As a result of the work of the Government it is estimated that land values have increased more than $105,800,000."

Of the many notable structures erected in the prosecution of this work, I will only mention two. The Roosevelt Dam in Arizona is a rubble masonry, gravity structure, with horizontal arch. Its extreme height is 280 feet and its crest is 1170 feet. The volume of masonry is 338,452 cubic yards. In building this dam and the works auxiliary to it 401,175 barrels of Portland cement were used, and of that quantity 338,452 barrels were manufactured by the Government near the site of the work.

The Arrow Rock Dam in Idaho is the highest dam in the world. It reaches a maximum height of 351 feet, and rises 260 feet above the bed of the stream; its crest is 1025 feet long, and its construction required 520,000 cubic yards of concrete masonry. In Washington, recently, I was privileged to listen to a lecture upon the reclamation projects of the Government, the interest of which was enhanced by a most beautiful series of stereopticon pictures.

We easily pass from dams built for irrigation and power to dams built for power purposes only, and to hydro-electric power developments at natural falls. In these developments the hydraulic engineer, the civil engineer, the mechanical engineer, and the electrical engineer make common cause, and all may be embodied in one man; but that would make him almost a phenomenal man. Whether it be team work or single harness, the results are wonderful and useful beyond measure. When hydro-electric developments come up for discussion, it would be strange if our thoughts did not turn to Niagara Falls, where, on the American side, two plants using 15,100 cubic feet of water per second are turning out 230,381 electrical horsepower, presuming that they are developing an efficiency of 80 per cent. There is a project, the plans for which have been submitted to me for advice, to take 6000 cubic feet per second from Lake Erie through a tunnel via Lockport and discharge it into Eighteen Mile Creek. This project proposes to utilize 312 feet of the entire fall from Lake Erie to Lake Ontario. If the 15,100 cubic feet per second used by the two existing powers were available for this latter project, that volume of water would yield 428,236 net electrical horsepower, or nearly twice the power now derived from it. There are many scores of water powers on our land which are interesting and more or less worthy of mention, but none possessing greater interest for the incarnate engineer than that now being constructed at Keokuk, Iowa, where the Mississippi is being held up and hereafter must pay toll in service before it can pass on its immemorial way in that channel which it has excavated for itself. This construction consists of a lock on the Iowa side built for the Government in return for the franchise under which the plant is being built. This lock is 110 feet wide, 400 feet of usable length, with forty feet of lift. Next comes the power-house, 123 feet wide, 1400 feet long, built to accommodate thirty turbo-generators. Some idea of the immense size of these turbines may be conveyed by the fact that the diameter of the draft tubes is eighteen feet. The weight of each apparatus is five hundred tons. The dam extending across from the power plant to the Illinois shore consists of a series of arched spans, 119 in number, thirty-six feet centre to centre of piers, and clear opening of thirty feet. These piers are six feet thick and forty-two feet wide; each opening is closed by a dam rising thirty-two feet above the bed of the stream, vertical on its up-stream side and ogee on its down-stream side. There are steel gates moved vertically with power mechanism on the bridge overhead by which the outflow over the dams is regulated. These gates are eleven feet high and long enough to close the thirty feet of opening between the piers. This plan will develop 200,000 electrical horsepower. This power will be transmitted 150 or more miles from the power site. A large block of it has been sold in St. Louis, distant nearly 150 miles. The dam creates deep slack-water navigation for sixty miles up stream. The progress of this work is among the marvels of celerity in modern construction, and our engineer is doing it.

To-day our cities must fetch their water from afar, unless —like my home city, Chicago—they have built beside great natural reservoirs. The city dwellers go no more with pitchers to the town pump, for our engineer has brought them water from remote fountains. He has led it through sheltered ways, along mountain sides, across valleys, and beneath rivers, and the life-sustaining fluid flows responsive to the turning of a faucet within the homes of the city dwellers. Two of the most memorable examples of water supply brought from long distances are found in our own land. New York has had to go farther and farther afield for her water supply as years brought her added thousands of thirsty people. The last watershed which she has made her own, within which the Ashokan dam is to bar the outflow of water, save as man liberates it, must furnish its supply through ninety-three miles of aqueduct; fifty-six miles of this distance is in "cut and cover," fourteen miles in grade tunnels, six miles through steel pipe siphons, and seventeen miles through pressure tunnels. One of these pressure tunnels passes under the Hudson River, dropping down 1150 feet below the surface to find suitable material through which to bore it.

This is what our engineer is doing for the greatest city of our country on the Atlantic coast. He is doing even more things for a little city on the Pacific coast. He is building an aqueduct to carry water to Los Angeles from Owens Valley, into which Mount Whitney looks from its cap of everlasting snow, 14,502 feet above sea level, and around which twenty-three other peaks of lofty eminence are gathered; and all of these give of their melting snow to make Owens River, which drains 2800 square miles of area. This aqueduct traverses 230 miles of country that challenges the courage, the endurance, the skill and fidelity of the engineer, but he is meeting every demand of the mountains and the deserts, and as a result 260,000,000 gallons of pure water daily will flow through the channels he has created.

This work is unique, for it is absolutely municipal. The city of Los Angeles has reposed its faith in the chief engineer and the loyal men he has grouped around him. They have planned the work, organized the working force, about 5000 men, which they house and care for and direct. They manufacture the cement which is used in the work, and their progress has been record breaking, besides showing an economy which, compared with bids at first received, indicates that the cost will be about half of what it would have been had the work been let to contractors.

In our cities the engineer has been busy striving to provide adequate facilities to keep pace with the urban needs, for transportation, for sanitation, for light, for heat; to build harbors for our marine commerce, and to make convenient and economical provision for interchange between land- and water-borne commodities.

In the matter of sanitation, he builds sewers to carry off the noxious spewings of the city; he builds canals to carry away the effluents of the sewers; he builds filtration plants to remove impurities from potable water, and he builds other filtration plants to render sewage innocuous before it passes into natural streams.

The mining engineer has gone into the fastness of the mountains and into the deep places of the earth and brought out coal and gold and silver and all manner of precious things, adding to man's comfort and his usefulness, and his happiness as well.

The electrical engineer has carried us into new realms of light before which all previous illuminants pale their "ineffectual fires." He can tell you that electricity *is*, but he cannot tell you *what* it *is*. I was told some years ago at Niagara that when Lord Kelvin was there a short time previously he visited one of the power plants then in the process of construction. A young engineer—ignorant of the great personality he then encountered—was very kind in showing him over the work and telling him all that he knew about it. When they were about to part, Lord Kelvin said: "My young friend, you have been very kind and have told me some very instructive things. Let me ask you, 'What is electricity?'" The young man answered, "I do not know, sir." The great man said: "Then at last we stand upon the same plane." Not only can the electrical engineer tell you that electricity *is*, but he can demonstrate to you its wonderful usefulness in the fields of industry and art.

The engineer has borne his part in the building of the Republic, and may we not paraphrase Tennyson and say *what he has done*, but the earnest of the things that he shall do.

Interference Points with a System of Right-angled Prisms. H. SCHULZ. (*Phys. Zeitschr.*, xii, 1211.)—When a pair of right-angled prisms are placed with their hypothenuse surfaces nearly in contact, leaving only a thin film of air between, a peculiar system of colored points is seen on looking in a direction normal to the film, near the extremities of the hypothenuse. The phenomenon is explained by the crossing of two sets of interference bands. Both sets of bands are due to the splitting-up of rays by the thin film of air, but in one case the rays undergo reflection at the three interior faces of the upper prism before entering the film of air to form the bands; in the other case the rays undergo reflection at the three faces of the lower prism after the bands are formed by the film. In the first case the interference bands are seen direct, in the second they are seen reversed, and the two sets of bands appear crossed. The phenomenon may be rendered more conspicuous and extended over a wider region by silvering one side face of each prism. The higher the reflection coefficient of the hypothenuse, the more favorable the distribution of intensity for observation of the phenomenon. Under certain conditions, by suitably silvering the hypothenuse surface, both sets of bands may be seen double, resembling the appearance with polarized light. A later paper will deal with the resolving power of this prism-system, and the possibility of utilizing it to distinguish very small differences of wave-length.

RECENT DEVELOPMENTS IN STEAM TURBINES.*

BY

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WESTINGHOUSE TURBINES.

In the early experiments made at The Westinghouse Machine Company, under the direction of Mr. George Westinghouse, a system of turbine elements was developed by Mr. Westinghouse consisting of a combination impulse turbine for the high-pressure stages, and reaction or Parsons elements for the low-pressure portions of the turbine, the object of the combination being to secure, without sacrifice in economy, a more stable mechanical construction by shortening the machine and dispensing with the necessity for three balancing pistons, as obtained in the Parsons design originally exploited.

This combination was particularly desirable at the time of its introduction by Mr. Westinghouse on account of the relatively low powers then required in turbo-generator work, although very successful machines have been in operation here and abroad of the straight Parsons design, which lends itself admirably to certain operating conditions.

The ability of the Curtis element to extract at a given blade speed considerable energy in the high-pressure stage of the turbine with good efficiency resulted in its adoption by Mr. Westinghouse for the high-pressure portion of his machine, by which 20 per cent. to 50 per cent. of the energy of the total expansion is extracted, leaving to the Parsons blading in the low-pressure portions of the turbine the balance of the work to be done with the most efficient turbine elements.

The impulse wheel in this construction replaced a large number of rows of Parsons blading with equivalent economy, because in the smaller powers it was necessary in the straight Parsons machine, on account of total peripheral admission, to make the blade speeds relatively low in order that their height might be as large as practicable, to reduce the proportion of leakage by the end of the blades due to the necessary blade clearances. Such a construction of spindles is shown in Fig. 31, where the comparison is obvious.

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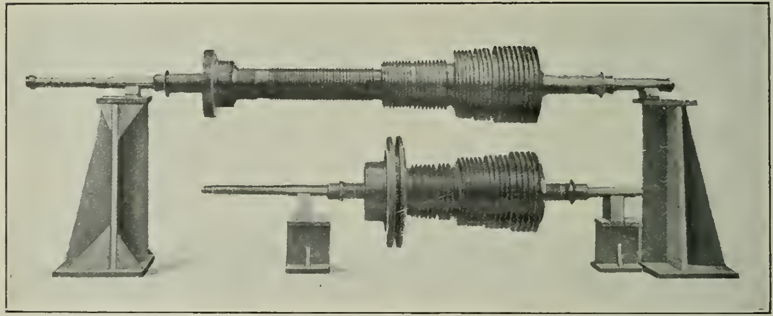
* Continued from page 128.

As this development proceeded, the demand for higher capacity generators increased, and to meet this demand it was necessary to materially enlarge the low-pressure portions of the turbine, which, in some instances, required a dividing of the Parsons blading into two sections, commonly known as the double-flow low-pressure expansion.

In 1903 Mr. Westinghouse filed his application for patent on the combination impulse reaction double-flow turbine illustrated in Fig. 32. With this construction the balancing pistons required by the straight Parsons machine were entirely dispensed with, and while for double-flow construction twice the number of blades were required as for similar conditions with single-flow, yet the application of the impulse wheel to the high-pressure stages made possible, in a great many instances, the proper mechanical design, on account of the considerable shortening of the turbine due to the introduction of the impulse wheel, thus allowing a length of spindle and cylinder of proper mechanical stability.

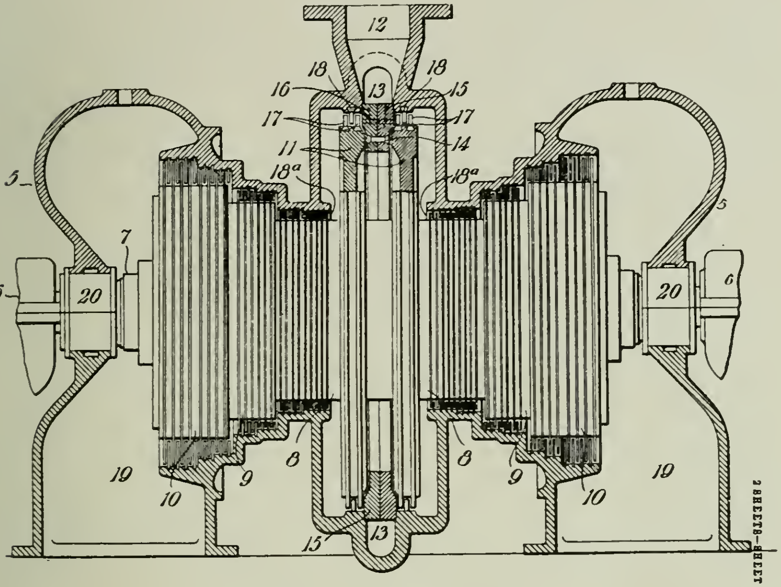
Fig. 31.



Rotors of two 500-horsepower steam turbines; upper spindle with complete reaction blading, lower spindle with impulse and reaction blading.

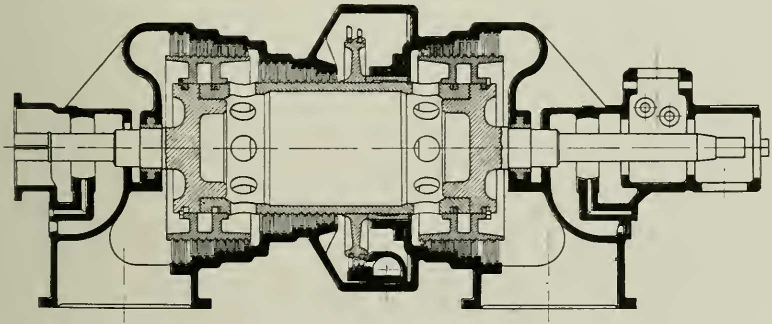
As this development progressed it was found advisable, on the score of efficiency, to resort to the Westinghouse single double-flow construction. This differs from the straight double-flow principle in utilizing a single Curtis impulse wheel with two rows of revolving blades, followed by a single barrel of reaction blades, after which half of the steam is allowed to pass through the drum around a balancing piston (for the single barrel of Parsons blades) to half of a double-flow expansion of reaction blading, and thence into a double exhaust opening at

FIG. 32.



G. Westinghouse fluid pressure turbine.

FIG. 33.



Turbine assembly, longitudinal section. Semi-double-flow turbine.

either end of the turbine, as illustrated in Fig. 33. The intermediate reaction blading was thus allowed to be proportioned with blades of twice the height and half the number as would have obtained had the entire reaction blading been made double-flow.

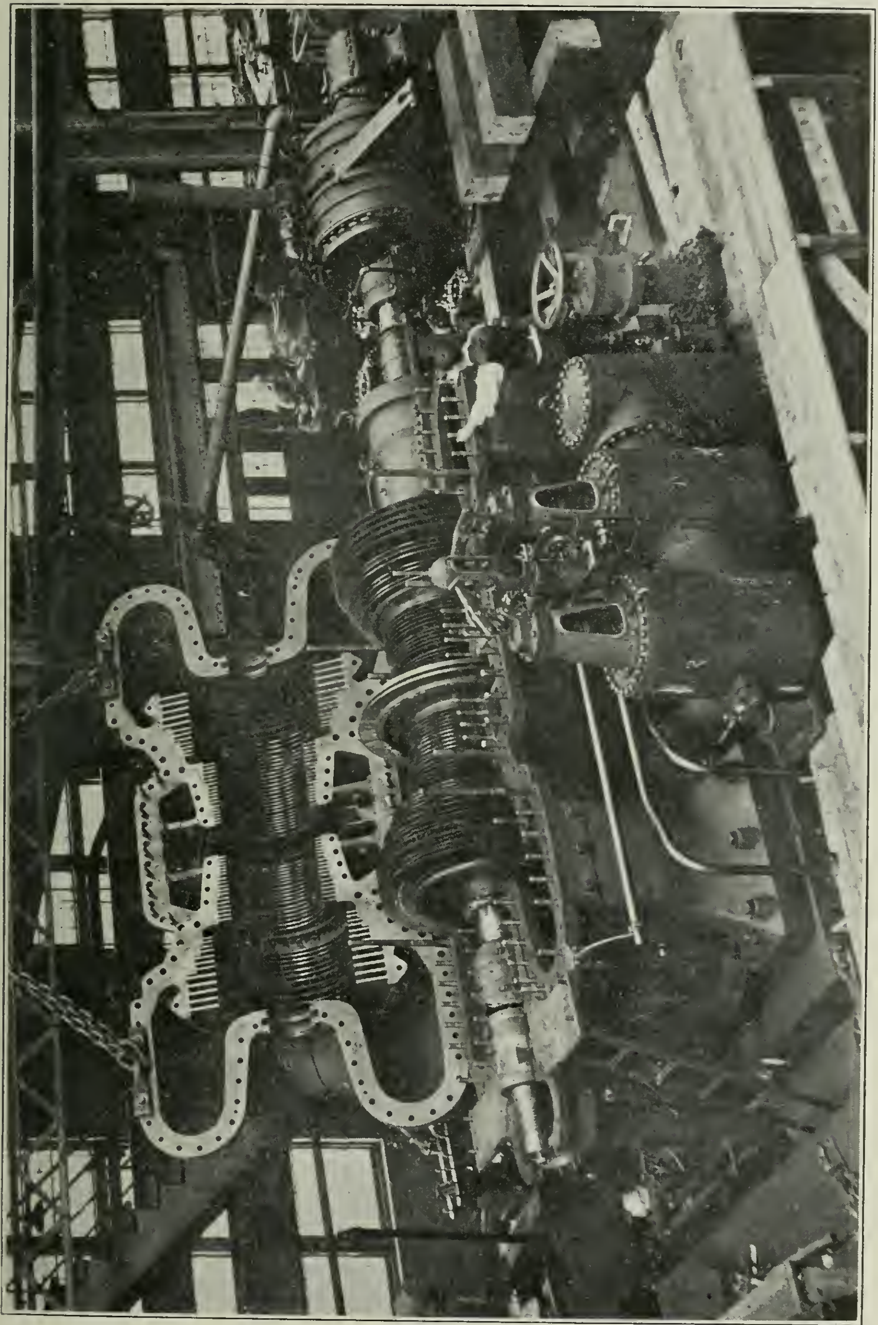
Since the efficiency of reaction blading is a function of its length, assuming the blade clearances the same, it is apparent that this single double-flow construction is adaptable to turbine units of moderately high capacity, depending on the rotative speed. This construction is now used in turbo-generator units for alternating current from 3000 to 10,000 kilowatts at speeds of 1500 to 1800 revolutions per minute.

In the development of the higher-powered turbo-generator units (above, say, 10,000 kilowatts at 1500 or 1800 revolutions), owing to the large volume of steam handled, the best proportioning results by making the reaction blading double-flow with a Curtis impulse wheel carrying two rows of blades and utilized in the high-pressure portion of the turbine. Here the reaction blading may be operated at sufficiently high blade speeds to materially reduce the number of rows and make a comparatively short machine, notwithstanding the fact that twice the number of rows of blades are required on account of the double-flow principle than would be necessary if single-flow elements were resorted to. Fig. 34 shows such a construction for a machine of 15,000 kilowatts, maximum rating at 1800 revolutions per minute.

These various constructions have, as will be seen, their particular field of usefulness, depending on the operating conditions and the speeds for which the turbines are designed.

The great importance in the turbine art of this combination turbine has been realized principally in the past five years in the field of electric-power generation, because it gives great flexibility and permits the use of high pressures and high superheats without the deleterious effect these operating conditions might impose with the more difficult mechanical construction of long cylinders and spindles subjected to wide ranges of pressure and temperature. The effect of the combination machine may perhaps better be understood by taking the following practical example, which assumes operating conditions now common in Europe and being introduced in this country:

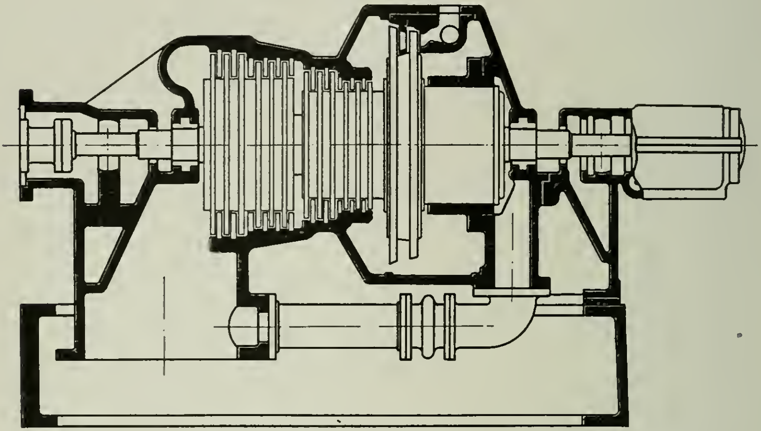
FIG. 34.



10,000-kilowatt turbine. Built for the City Electric Company, San Francisco.

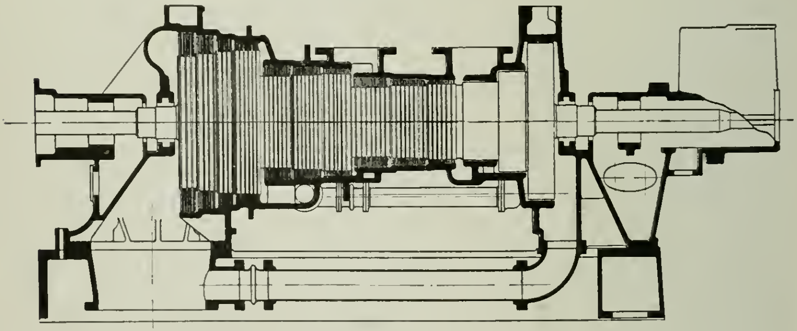
Steam is to be delivered to the turbine at 200 pounds pressure gauge and 150 degrees superheat, and is to be expanded to 28½ inches vacuum. Its temperature, therefore, entering the turbine would be 538° F. With the Westinghouse turbine the steam would enter the nozzle chamber and be expanded through the nozzles to 78.8 pounds absolute with the impulse wheel operating at a blade speed of 500 feet per second. Its temperature and pressure would therefore be in the impulse chamber 328° F. and 78.8 pounds absolute respectively, which

FIG. 35.



Turbine assembly, longitudinal section. Single-flow turbine with impulse element.

FIG. 36.



Turbine assembly, longitudinal section. Single Parsons type turbine.

are sufficiently low to give an entirely satisfactory mechanical construction of the low-pressure end. The construction of such a turbine is shown in Fig. 35. If the steam expansion were to take place in the equivalent Parsons turbine, the construction would be as illustrated in Fig. 36. By comparing the two it will be seen that a very material shortening of the spindle is secured by the replacement in the Parsons turbine of the high-pressure portions, corresponding to the equivalent expansion as would take place in the nozzles of the impulse wheel, and with the same efficiency, because the impulse wheel replaces the most inefficient portion of the Parsons turbine.

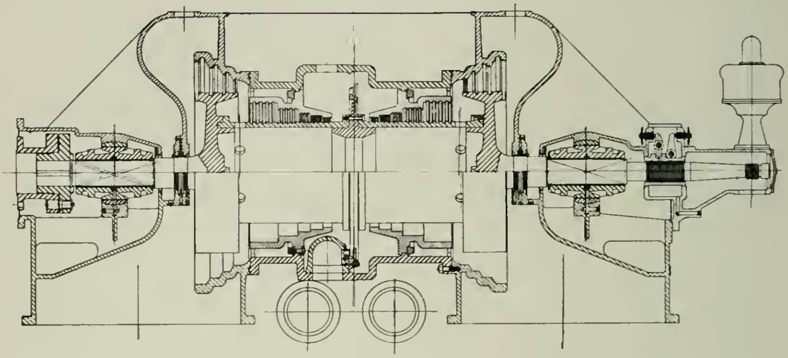
In the matter of economies at fractional loads the substitution of the impulse element for its equivalent Parsons blading in the high-pressure portion of the turbine allows greater efficiency, because, with the impulse construction, nozzle control can be resorted to, thus converting into useful work a portion of the energy of the steam which would be lost in a straight Parsons turbine due to throttling. In other words, with the nozzle control construction the impulse wheel becomes an efficient reducing valve when the turbine is operated at fractional loads.

While this advantage may not in a good many instances be very material, and may not warrant the ordinary complications incident to nozzle control, yet in principle it is proper to utilize it for the same flexibility with greater efficiency, and it is only necessary to design a mechanical nozzle control apparatus whose complication is less than the advantages gained by the economies in its use in order to make this arrangement a most satisfactory and desirable one.

The great flexibility of reaction blading over wide variations of pressure distribution, and its adaptability especially to handling large volumes of steam efficiently, make its application particularly desirable in the low-pressure portions of turbines. There are, however, operating conditions now arising in power-plant development which make more suitable the adoption of reaction blading for the high-pressure portion of turbines than has heretofore obtained. This condition has been particularly brought about by the development of the alternating-current generator to operate at high speeds, generating large power. This can probably best be illustrated by some recent designs prepared by The Westinghouse Machine Company for generator units of 15,000, 20,000, 25,000, and 30,000 kilowatts capacity.

In such units it is of the utmost importance to secure the very maximum of economy in steam consumption, because the output of the units is so enormous that a small loss in efficiency means a very large increase in the cost of operation.

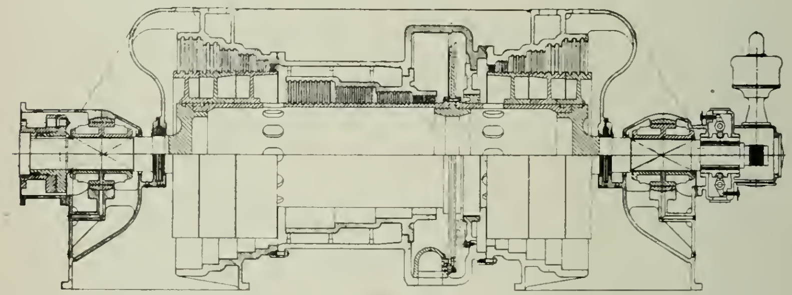
FIG. 37.



25,000-kilowatt steam turbine, condensing, 1500 revolutions per minute

With the development of the electrical art, alternating-current generators of 5000 kilowatts can be built at 3600 revolutions per minute, from 5000 to 25,000 kilowatts at 1800 revolutions per minute, and from 5000 to 30,000 kilowatts at 1500 revolutions per minute, the different speeds corresponding to 60 and 25 cycles, as used in this country. Likewise, the tur-

FIG. 38.

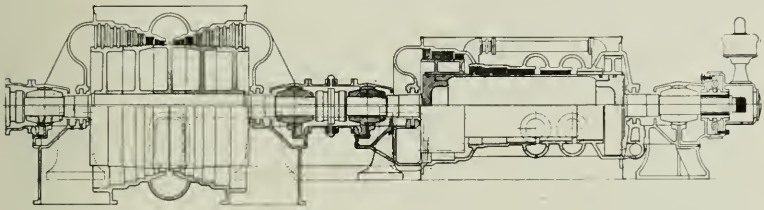


25,000-kilowatt steam turbine, condensing, 750 revolutions per minute.

bine is susceptible of generating in one unit the necessary power to drive the above generators at these particular speeds.

Some two years ago designs were proposed by The Westinghouse Machine Company for a 25,000-kilowatt unit to operate a 25-cycle generator with operating conditions of 200 pounds steam pressure, 200 degrees superheat, and 29.2 inches vacuum.

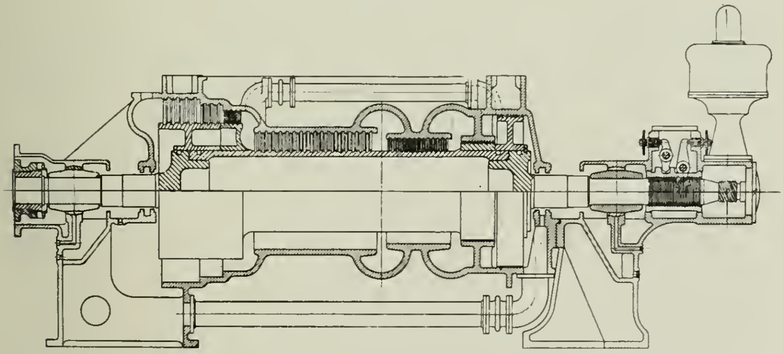
FIG. 39.



20,000-kilowatt steam turbine, 200 pounds boiler pressure, 750 revolutions per minute, condensing.

Four solutions of this condition were worked out, as follows: (1) A Westinghouse double-flow turbine at 1500 revolutions per minute, direct connected to a 25-cycle generator of 25,000 kilowatts maximum capacity, as illustrated in Fig. 37. (2) A single double-flow Westinghouse turbine running at 750 revolutions, direct connected to a 25,000-kilowatt generator, as illustrated in Fig. 38. (3) A tandem compound Westinghouse-Parsons turbine at 750 revolutions per minute, the high-pressure portion being single-flow and the low-pressure portion being double-flow, direct connected to a 25,000-kilowatt

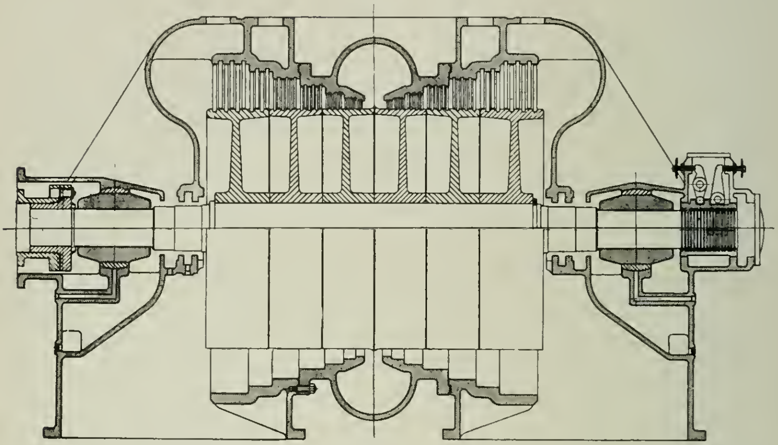
FIG. 40.



20,000-kilowatt steam turbine, high-pressure element, 200 pounds boiler pressure, 1500 revolutions per minute.

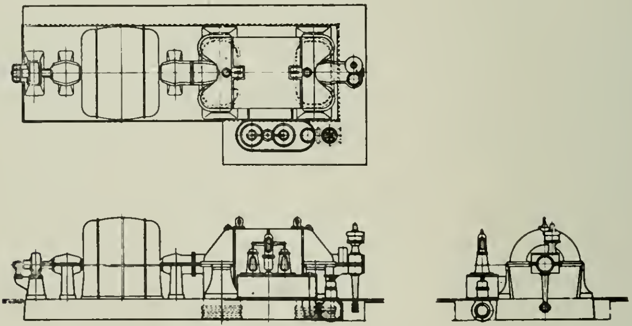
generator, as illustrated in Fig. 39. It is evident that this machine could be arranged cross-compound with two generators of 12,500 kilowatts each. (4) A cross-compound Westinghouse-Parsons turbine with the high-pressure portion running at 1500 revolutions (Fig. 40), direct connected to a 12,500-kilowatt generator, and a double-flow, low-pressure, Westinghouse-Parsons turbine running at 750 revolutions, direct connected to a 12,500-kilowatt generator, illustrated in Fig. 41. Fig. 41A shows the comparison to scale of the machines in 1, 2, 3, and 4 respectively.

Fig. 41.



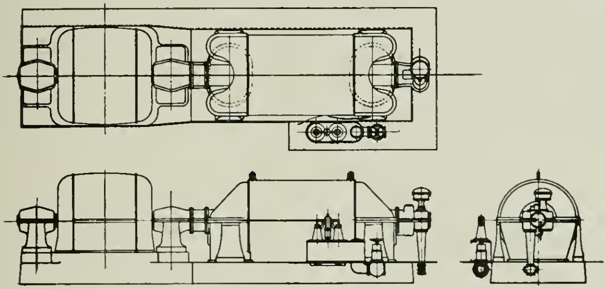
25,000-kilowatt steam turbine, cross-compound condensing, high pressure 1500 revolutions per minute, 750 low pressure revolutions per minute. Section through low-pressure cylinder.

Fig. 41A.



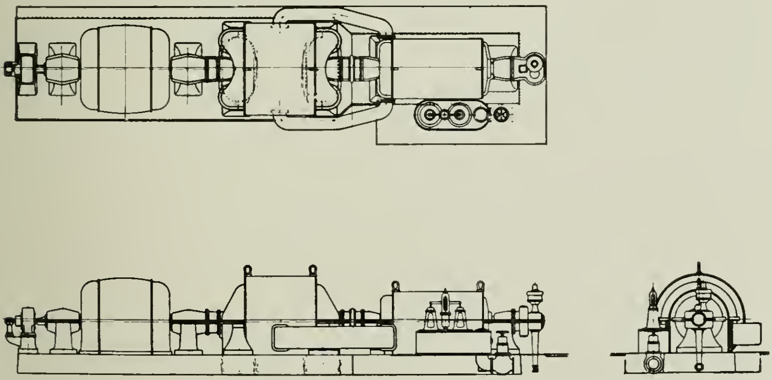
All of these arrangements would give very excellent economy, and the choice of the unit would depend primarily on the two factors of first cost and economy, assuming that in each case the reliability for continuous operation is the same.

FIG. 41B.



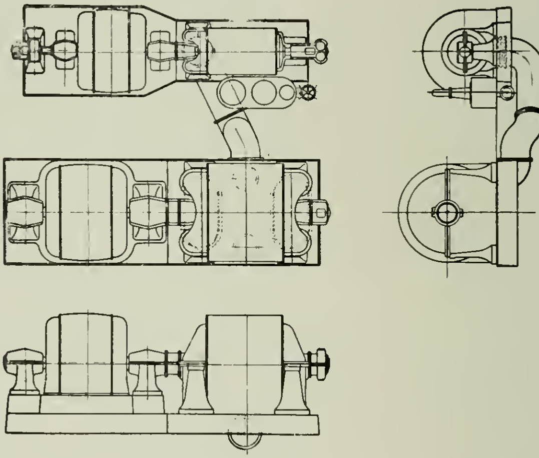
A close study of the four arrangements indicates that the Westinghouse double-flow turbine at 1500 revolutions per minute, direct connected to a single generator (Fig. 37), is the cheapest construction. The large areas required in the low-pressure stages of this turbine make high velocity and long length of blade essential, with the necessity of careful designing to properly take care of the stresses due to centrifugal force in the low-pressure end.

FIG. 41C.



The most economical combination of the four is the cross-compound Westinghouse reaction turbine with the high-pressure portion running at 1500 revolutions and the low-pressure portion at 750 revolutions. With this arrangement the highest efficiency is obtained, because with the large volumes of steam required to develop the high power and the ability to combine the unit into high- and low-pressure cylinders, running at 1500 and 750 revolutions per minute, gives the condition for best blading proportions throughout the turbine without departing from standards of practice already established. This machine would be very remarkable for its high efficiency, which it is believed could not be reproduced with any other known form of turbine. The construction, however, is considerably heavier than the single unit commented upon above, and would be more costly to construct and install.

Fig. 41d.



In such a case as the one cited there is little doubt that the cross-compound Parsons machine will give the maximum efficiency. At powers and speeds attainable with single alternating-current units of, say, below 15,000 kilowatts capacity the Westinghouse double-flow turbine between 10,000 and 15,000 kilowatts will be nearly, if not equal, to the cross-compound straight reaction turbine under like operating conditions, and any difference in efficiency would probably be offset by the difference in first cost in favor of the Westinghouse double-flow machine. Between 10,000 and 4000 kilowatts capacity the Westinghouse single double-flow machine would undoubtedly be the proper construction, taking into consideration the first cost and efficiency.

The demand for turbo-generator machines is greatest in kilowatt output between the sizes of from 4000 to 15,000 kilowatts maximum rated capacity, within which range the Westinghouse single double-flow and Westinghouse double-flow machines most admirably meet the commercial conditions both with respect to cost and efficiency.

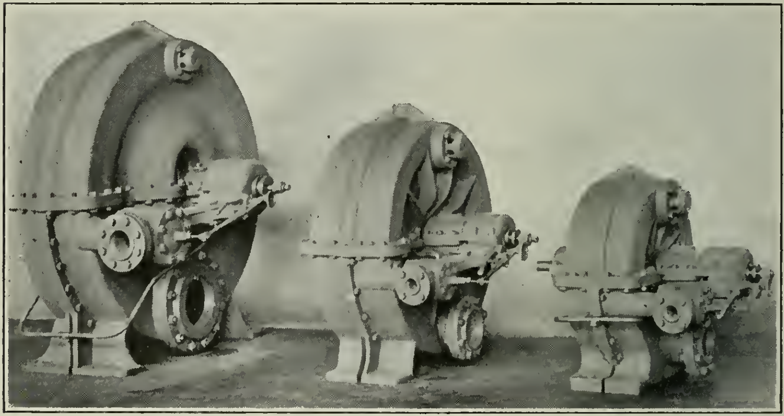
Below 4000 kilowatts capacity the Westinghouse turbine consisting of (1) an impulse wheel followed by single-flow reaction blading, illustrated in Fig. 35; (2) an impulse wheel followed by single double-flow reaction blading (Fig. 33); (3) an impulse wheel followed by double-flow reaction blading (Fig. 37), and (4) a single-flow Westinghouse reaction turbine (Fig. 36), represent the various choice of machines best suited for operating conditions (*a*) dependent on the initial pressure and superheat, (*b*) on the number of revolutions at which the generator or other driven machine rotates, and (*c*) on the capacity.

Thus with a speed of 3600 revolutions per minute, driving a 60-cycle generator at, say, 3000 kilowatts, the turbine design would follow the combination impulse double-flow reaction machine for best efficiency and lowest cost (Fig. 37). If, however, the generator to be driven was 25-cycle, with an allowable maximum speed of 1500 revolutions per minute and a capacity of 3000 kilowatts, the choice would lie between a design of a straight single-flow reaction turbine and a combination impulse single-flow reaction turbine, the former being used for moderate degrees of superheat and initial pressure, and the latter for high superheat and high pressure.

In general, however, the application of the Westinghouse turbine, consisting of an impulse element for the high-pressure portion and reaction blading for the low-pressure portion, is admirably adapted for complete expansion turbines over wide ranges of power and speed, and since the introduction of this type in 1903, following the initial designs by Mr. Westinghouse, a large proportion of the firms building steam turbines have utilized this construction, either with Parsons or Rateau blading, following the Curtis impulse element or elements in the high-pressure end.

The advantages of the Westinghouse type are: (1) the ability to shorten the machine by the introduction, in the high-pressure stages, of an impulse wheel of the Curtis type without material loss in efficiency where the powers and speeds are relatively low; (2) the reduction of pressure and temperature within the turbine cylinder by expanding the steam initially in fixed nozzles; (3) the elimination of two or more balancing pistons as obtain in the straight Parsons machine, consequently reducing the small, balancing piston clearance, and leakage of steam incidental to their introduction; (4) the retention of the most efficient turbine elements in that portion of the machine where they can be most effectively employed for efficiency; (5) the ability to secure higher economies at fractional loads by the introduction of nozzle control on the initial impulse element; and (6) the retention of the drum construction for rigidity of spindle and low cost of manufacture, referring particularly to the reaction blading.

FIG. 42.

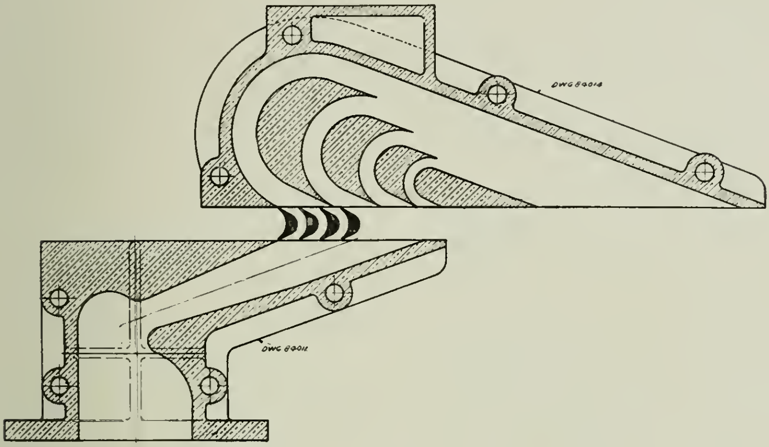


Group of S. N. C turbines.

The disadvantages of the Westinghouse construction are: (1) for extremely high powers, say, above 15,000 kilowatts capacity, the impulse wheel is less efficient than its equivalent Parsons blading, depending, however, on blading proportions; (2) for capacities of 300 kilowatts at 3600 revolutions per minute, and 750 kilowatts at 1500 revolutions per minute, the construction, while applicable at these powers and speeds, becomes as expensive with the same efficiency as turbines of other designs.

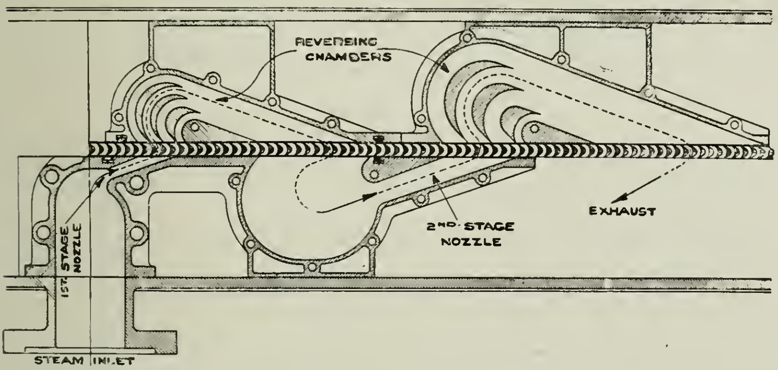
For the smaller powers, therefore, The Westinghouse Company developed some three years ago impulse turbines of the re-entry type, illustrated in Fig. 42, which are adaptable down to units of 1 kilowatt capacity, having the advantage of one revolving row of blades, with which it is possible to obtain (*a*) a subdivided impulse turbine with one reversal (Fig. 42A), equivalent to a Curtis turbine with two revolving rows of blades, used for

Fig. 42A.



S. N. C. turbine. 05 S. N. C. nozzle blocks and reversing chamber.

Fig. 43.



S. N. C. turbine. Arrangement of nozzles and reversing chambers, showing action of steam. Two stages, with two velocity drops to each stage.

medium-pressure drops; (*b*) a subdivided impulse turbine with two reversals (Fig. 43), equivalent to two Curtis elements with four revolving rows of blades, and (*c*) subdivided impulse elements with one or two reversals followed by one or more Rateau stages, or a series of Rateau stages without Curtis elements.

This construction has the advantage of the simplicity of the De Laval turbine operating efficiently at such rotative speeds as are commercially required for the purposes of direct connection to generators, pumps, blowers, and other machines which require relatively good efficiency with relatively low speed of rotation.

COMPARISON OF STEAM TURBINES.

Comparison of the relative merits of the turbines previously described cannot be fairly made in any general terms, as certain combinations of turbine elements must be varied to suit the particular operating conditions which may be imposed. If, however, the discussion be limited to the most common type, namely, the complete expansion turbine and its operating requirements, subdivided with definite conditions imposed, the general condition influencing the selection of a good type may be stated.

The three principal items in considering the complete expansion turbine for commercial purposes are (1) reliability, (2) capacity, (3) economy.

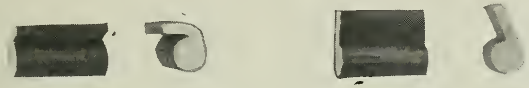
RELIABILITY.

In general, it may be stated that the reliability of turbines of different types depends more on the design of the details than on the inherent merits of the turbine elements themselves.

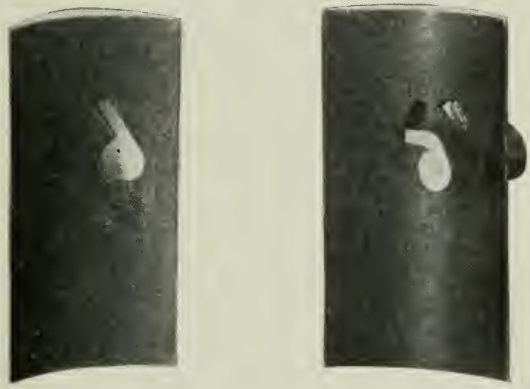
One of the principal items in detail design to which all turbine builders pay particular attention is the method of fastening the blades to the disks or drums, as the case may be. For many years after the introduction of the Parsons turbine the blading was secured to the drums by the well-known method of inserting, alternately, in a slightly dovetailed groove, the blades and packing pieces, and after a row had been so inserted in its groove, the packing pieces were caulked between the blades, to secure them by friction, as well as by a small nick in the base of the blade. As the development in turbine design progressed it was found necessary with longer blades to lash the ends in some manner. Some ten years ago this was accomplished by silver-soldering a strip into the blades to secure the desired rigidity, but principally to prevent their vibration, due to their rotative speed and the velocity of the steam passing through them.

This general method of blading was devised by Mr. Parsons in 1896, and has been followed for a number of years by builders of that type of turbine. To those skilled in turbine blading work the caulking process is known to be an excellent blade fastening. The first change which was made in this country in the Parsons form of blading was in the adoption of a different method of shrouding the blades, which consisted of punching a hole, in the shape of a comma, near the end of the blade and inserting therein a wire, drawn to the comma section. After the blades have been inserted in the spindle and cylinder and the comma wire put in place, a tool is used to shear the tail end of the comma at each blade and bend it around, as illustrated in Fig. 44. When this operation is performed, it is evident that there exists between

Fig. 44.



Caulked Original



Blade punched. Blade lashed.

Samples of the Westinghouse blade lashing.

the blades a tight strut which effectively diminishes the tendency to vibration, is easily applied, and makes a much better and safer construction than the old method of silver-soldering. This construction substantially amounts to shrouding the blades without, however, creating any blank space between the real tip of the blade and the cylinder or spindle.

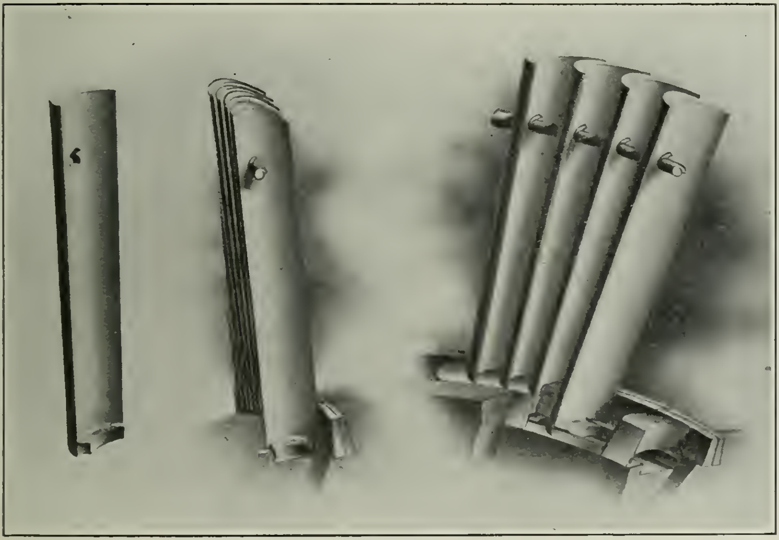
This lashing or shrouding of the blades prevents their individual vibration, but does not prevent their vibrating as a group.

It is a fair statement to make that scarcely any turbine of anybody's make ever gave trouble due to the blades breaking or coming out because of centrifugal force. It is not centrifugal force that breaks the blades, but vibration of the blades themselves, and until lashing of the longer blades was resorted to, breaking was occasioned by the individual vibration. The lashing or shrouding of the blades therefore reduced very materially this difficulty. Twelve years ago The Westinghouse Machine Company experienced some unaccountable breaking of blades which were made of bronze. This was attributed to fatigue of the metal of the blade, or repeated heating and cooling, and led, as a cure to the difficulty, to the adoption of steel as blade material. Later experience and analysis of these troubles reversed the impression first obtained and led to the conclusion that the difficulty was really due to blade vibration.

In the last few years the capacities of turbines have increased so enormously, resulting in long blade lengths, that it became necessary to devise better means of insuring blade stability, and with this in view the Westinghouse Company has developed in the past two years the blade construction illustrated in Fig. 45. The lashing or shrouding must not be continuous, as provision for expansion and contraction must be made, since the coefficient of expansion of the spindle or cylinder, as the case may be, is not the same as that of the blades, the material being different. Therefore, all lashed or shrouded blades must be arranged in segments not exceeding, say, two feet in length for large diameters. There is no reason, however, why the segments of blading will not vibrate as a whole, just as the individual blades do when not properly lashed, except that on account of lashing or shrouding the frequency of vibration will be very much higher, and the amplitude consequently less. Lashing or shrouding, therefore, is a palliative against vibration, and not a cure. It is the practice of the firm with which I am connected to lash all reaction blades above one inch in length, and very long blades may have as many as three or four rows of lashing wire.

The desirable thing, therefore, in turbine blading is to provide a blade which, since it is impossible to entirely eliminate vibration, will be of such form that the vibration, should it exist, will not concentrate the stresses at any one point. A turbine blade might be likened to a leaf spring secured at one end, with the other end free to vibrate. If this leaf spring has a tapering section so that when loaded at its outer end the stresses throughout are uniform, it may be allowed to vibrate indefinitely without breaking. If the condition is reversed and the greatest section of the spring is at the outer edge, it will, on being deflected, have such deflection concentrated at the inner end close to the point of support. The concentration of these stresses at the supporting point would, in a short time, cause failure of the material and the breaking of the spring. If the spring were made of a uniform section throughout its length the

FIG. 45.



Turbine blading.

condition would, of course, be better than that as last stated, but it would be a question of sufficient time and sufficient amplitude of vibration for the fracture to take place at the point of support.

Some turbine builders diminish the section of the blade at the point of support; others maintain a straight section, while in the modern development of the Westinghouse construction (Fig. 45) the base of the blade where it is inserted in the spindle or cylinder is, in the process of manufacture, upset to a thicker section than at any other portion, such thickening extending beyond the point where the blade issues from the groove. It will also be noticed that there is provided an absolute interlocking system, the strength of the under-hanging foot of the blade being equal to that of the blade itself; also that this construction involves no caulking process which requires skill and is difficult to inspect. The foot at the ends of the blades is obtained by upsetting or forging, and the dies for carrying out this operation are so constructed that the blade material is increased at the root, tapering off to a standard blade section some distance above the surface of the blade-carrying member. This effectually eliminates concentration of stresses at the root of the blade and gives a construction approximating a beam of equal stress.

The advantages, therefore, of this new type of reaction blading may be summarized as follows:

(1) Absolute interlocking of the blades with the blade-carrying member, the strength of all fastening means being equal to the strength of the blades themselves.

(2) No caulking is employed. This permits ready inspection of the blades before insertion, and assurance that they are firmly secured when installed.

(3) The blades may be easily removed from their grooves and replaced an indefinite number of times without mutilation or injury to the grooves.

(4) The section of the blading is tapered, being heavier at the root, eliminating danger from vibration of the blades.

Development in blade-holding means for impulse turbines has been necessitated in the last two or three years, due to the increase in blade speeds. Prior to three years ago the blade speeds of the impulse wheel of the Westinghouse type did not exceed 400 feet per second. The blade fastening in the construction used in these wheels is as shown in Fig. 46. The more recent developments, however, with the increase in impulse blade speeds, have resulted in the construction shown in Fig. 47, which materially reduces the weight of the impulse wheel at its head, and consequently the stresses in the disk, at the same time giving a blade fastening which is as strong as the blade itself. With this arrangement blade speeds of from 600 to 700 feet per second may be obtained without undue stresses in a through disk construction.

FIG. 46.

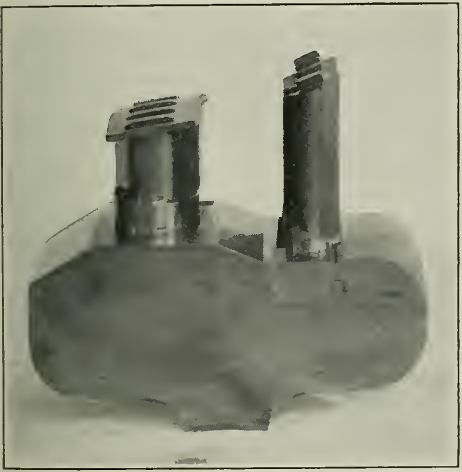
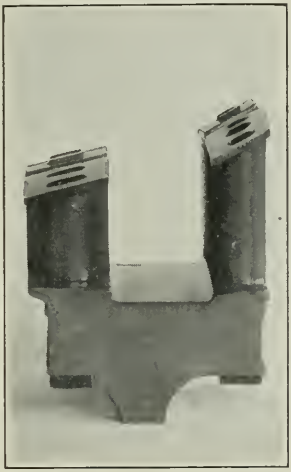


FIG. 47.



Blade fastenings.

Many details of design have been refined as the development of the turbine has progressed, such as better proportioning of cylinders and spindles to withstand distortions due to differences in temperatures, the supporting of the cylinders on the bed-plates, details of nozzle construction, balancing pistons, etc. Space will not permit a minute description of these recent developments, but it may be stated in general that in the early Parsons construction in 1900 it was thought impracticable to build units of larger capacity than 400 or 500 kilowatts without subdividing the cylinder construction into high- and low-pressure portions. The turbine represented in Fig. 30, constructed in 1901, marks a distinct advancement in the art in this respect, and was at the time of its introduction severely criticised for its large capacity, and predictions were made for its failure in service. This machine might be said to have been the forerunner of the enormous development in power capacities in turbine work, which to-day reach an output of from 20,000 to 30,000 kilowatts in a single cylinder.

MAXIMUM OUTPUT OF TURBINES.

It is evident that the De Laval turbine cannot be utilized for large capacity, and the comparison will therefore have to be made between the Westinghouse or Parsons turbine, the Rateau turbine, and the Curtis turbine.

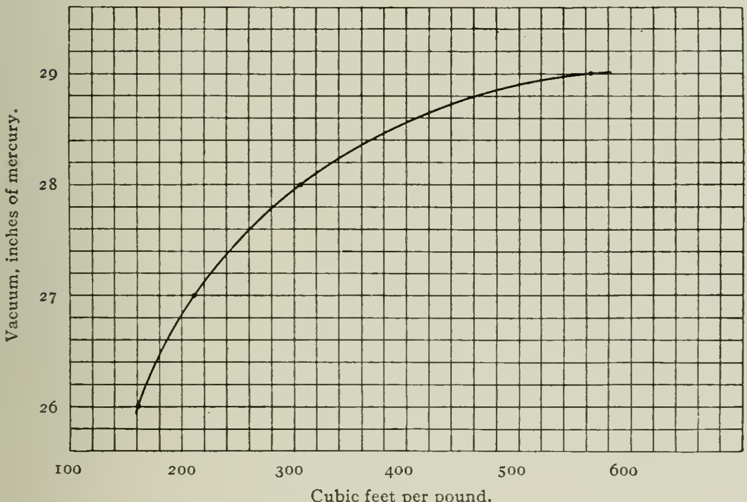
The maximum output of any turbine depends mainly on (1) the specific volume of steam at the exhaust of the turbine, which in turn depends on the vacuum; (2) the outlet velocity, which depends on the permissible leaving loss, and hence the efficiency; (3) the mean diameter of the blading of the last row of blades, which depends upon the maximum permissible peripheral speed; and (4) the maximum permissible blade height, which depends on the method of fixing the blade and the construction of that part of the spindle holding the last row of blades.

(1) Other things being equal in the Parsons, Rateau, and Curtis turbines, the specific volume of the steam passed by the last row of blades is the same, and with like blade speeds, blade heights, and blade angles no difference can exist between the three types as regards maximum capacity. Likewise, with equal blade speeds the leaving loss will be proportional to the outlet velocity. The maximum capacity of output, therefore, is dependent primarily on the length and mean speed of the last revolving row of blades and on the mean blade diameter, in any type of turbine. If a drum construction is used to carry the last row of blades, it can be shown that (other conditions remaining the same) a disk turbine can be built having twice the maximum output of a drum turbine. By those familiar with turbine construction, reaction blading is generally coupled with a drum construction. The recent designs of the Westinghouse high-power turbines, however, have the last rows of blading carried by a through disk and not by a drum, as may be seen by reference to Fig. 37.

The construction of the blade fastening in the Westinghouse turbine can be shown to be as strong as the blade itself; consequently the limit of output, considering the last row of blades in this type of turbine, would be proportional to the permissible stresses in a through disk, which allows, therefore, the maximum capacity that any turbine is capable of, and particularly so as the construction of the Curtis and Rateau machines involves a disk with a hole in the centre, which, as shown in Appendix III, cannot be as strong and reliable as a disk without a hole in the centre.

The specific volume of one pound of steam expanding adiabatically from 26 inches to 29 inches vacuum is plotted on the curve, Fig. 48. With a disk speed of 500 feet per second in the low-pressure end of the turbine there will be required, with reaction blading, two moving rows to complete the expansion from 26 inches to 29 inches vacuum. The height of the revolving blades to accommodate the increase in specific volume between 26 inches and 29 inches vacuum will be relatively as 1 to 3.4, depending somewhat on the capacity of the machine.

FIG. 48.

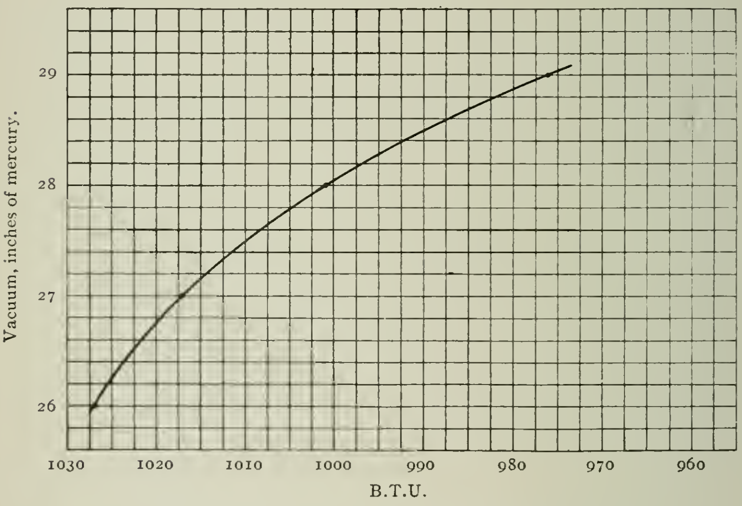


Specific volumes between 26 inches and 29 inches vacuum.

If the leaving losses in a Rateau or Curtis turbine are to be the same as in the reaction turbine, the last blades must be of equal length and equal speed for the same leaving loss and capacity, since the last moving row of the reaction turbine for like efficiency may be made an impulse blade, which would result in a reduction of the blade height compared to what it would be if made for pure reaction.

The energy in the adiabatic expansion of one pound of steam from 26 inches vacuum to 29 inches vacuum is plotted in the curve in Fig. 49, from which it will be seen that between 28 inches and 29 inches vacuum the energy is practically the same as between 26 inches and 28 inches vacuum. With turbines of high capacity, therefore, it is essential to obtain very high vacuum in the exhaust on account of the enormous energy contained in the expansion at low pressures. If we assume, therefore, that turbines of high capacity are built for operating conditions with high vacuum, say 29 inches, the last row of blades must be considerably higher than the preceding row to handle the large increase in specific volume of the steam passing to the exhaust. Again, as the stress in a disk due to the blades is proportional to the weight of the blade, the longer the blade and the higher the blade speeds, the greater the necessity for a construction to properly care for the stresses due to centrifugal force; and as the last one or two rows in the reaction turbine can be secured to a through disk, this design lends itself to a turbine of

FIG. 49.



Energy in B.T.U. between 26 inches and 29 inches vacuum.

maximum output, because (1) the rows immediately preceding the last rows of blades handle steam of considerably less specific volume, and (2) because in the reaction turbine a design with through disks supporting the last row or two of revolving blades can be made with such through disk construction, which, as shown in Appendix II, gives the maximum strength.

If the low-pressure portions are made double-flow, as is common practice with the reaction turbine, the maximum capacity obtainable is, of course, double the capacity of a single-flow machine. The facility with which reaction turbines are made double-flow, therefore, allows a maximum output of at least double the capacity obtainable in a design of Rateau or Curtis machines with equal blade speeds and equivalent operating conditions, and with equal reliability in service.

ECONOMY.

In order to compare the efficiencies which can be obtained with the Curtis, Rateau, and Parsons machines, reference is made to Figs. 10 to 16 inclusive, and to the consideration that the maximum efficiency for certain blade speeds in any type of turbine is dependent on (*a*) design of the blade elements, (*b*) the relative ratio of the velocity of the blades to the velocity of the steam, (*c*) the capacity of the turbine, and (*d*) the operating conditions.

Let $S_b =$ mean blade speed,
Let $S_s =$ mean steam speed,
Let $E =$ blade efficiency.

If steam is admitted to a wheel with one row of impulse blades (Fig. 10), at a certain speed, S_s, and the blades are revolved at different speeds, S_b, theoretically, the efficiency is at a maximum for a certain blade speed given by the ratio,

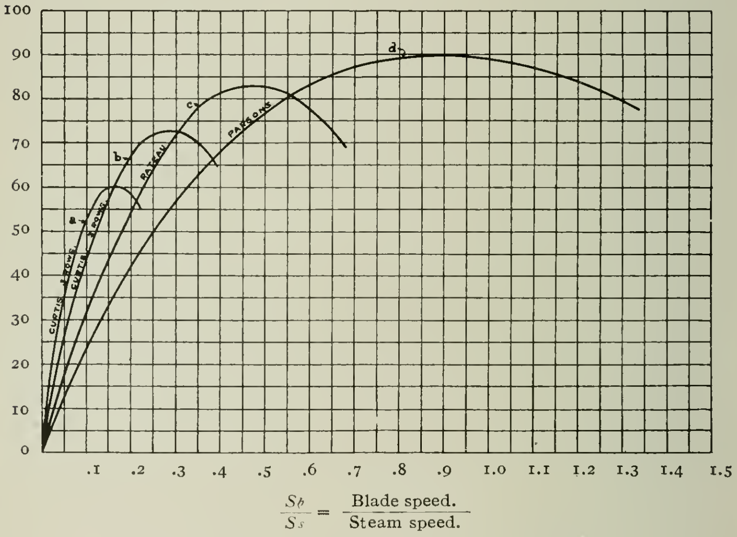
$$\frac{S_b}{S_s} = \frac{\text{mean blade speed}}{\text{mean steam speed}} = \frac{1}{2}$$

For any other ratios of $\frac{S_b}{S_s}$ the efficiency will be smaller, becoming zero when $S_b =$ zero and when $S_b = S_s$.

The actual maximum efficiency and the ratio $\frac{S_b}{S_s}$ at which it is obtained depend mainly on the angles of the blades and the frictional losses in the machine. Curve *c*, Fig. 50, represents a fair average of test results actually obtained in well-proportioned Rateau blading, the maximum efficiency being 82½ per cent. for $\frac{S_b}{S_s} = .47$ approximately.

For impulse wheels with two rows of moving blades the maximum efficiency is obtained for $\frac{S_b}{S_s} = .28$ approximately, as shown on curve *b*, Fig. 50, such maximum efficiency being 72½ per cent.

FIG. 50.



Efficiency curve. Parsons, Rateau, and Curtis wheels.

For impulse wheels with three, four, or five rows of blades the maximum efficiency is obtained for $\frac{S_b}{S_s}$ less than $^{1}/_{6}$, ⅛, and $^{1}/_{10}$ respectively. Of these, however, only the impulse wheel with three rows of blades is of practical importance, the actual efficiencies obtainable being given by curve *a*, Fig. 50, showing a maximum efficiency of 60 per cent. for $\frac{S_b}{S_s} = .17$ approximately. The efficiency of impulse wheels with more than three rows of moving blades is less, and they are therefore not used except in cases where efficiency becomes a secondary matter.

For reaction turbines with multiple stages properly proportioned, and with relatively large capacities, the maximum efficiency is obtained for $\frac{S_b}{S_s} = .9$ approximately, at which the efficiency obtained on test has reached 90 per cent., with corresponding reductions when greater or less values of $\frac{S_b}{S_s}$ are used, as given by curve *d*, Fig. 50. The total pressure drop with the best efficiency obtainable must have: one wheel with three rows of blades, maximum efficiency 60 per cent.; or three wheels with two rows of blades, maximum efficiency 72½ per cent.; or twelve wheels with one row of blades, maximum efficiency 82½ per cent.; or forty-eight rows of reaction blades with a maximum efficiency 90 per cent.

From a comparison of these efficiency curves it is evident that the reaction blading is most desirable for the low-pressure portions of turbines where the blade heights become suitable for maximum efficiency, due to the reduction in the percentage of leakage loss, which vitiates the efficiency of the blade in proportion to such loss, and consequently becomes greater as the height of the blade becomes less. With, therefore, a blade clearance of ten-thousandths of an inch in the low-pressure portion of a reaction turbine with blades ten inches in length, the loss would be approximately four-tenths of one per cent. If, however, the blades were one inch in length, the loss would be approximately four per cent.; and as the capacity of the turbine diminished, requiring smaller blade heights, the leakage per cent. would have sufficient vitiating effect on the economy to warrant the introduction (in place of the reaction blading in the high-pressure stages) of a Rateau or Curtis element to get equal efficiency and the large initial drop in pressure which is desirable for mechanical reasons, given elsewhere in this paper. On the other hand, where the volume of steam, and consequently the capacity of the turbine, becomes great, on the score of efficiency, the impulse elements in the high-pressure stages can be dispensed with to advantage, because the reaction blading gives, under such conditions, reaction blade proportions for maximum efficiency. Such a condition has already been discussed in comparing the relative merits of designs for a 25,000-kilowatt machine.

The frictional resistance due to the revolving parts would undoubtedly favor the drum construction or reaction turbine, because the surface exposed in an equivalent design becomes less than in equivalent Curtis and Rateau machines.

The losses are, in any event, a small proportion of the total output of the machine, especially in high capacities, and the comparison of the advantages of the different types in this respect may be eliminated.

The improvement in economy due to the development of turbo-generator units up to 1906, of turbines built in this country, is indicated in Table I.

The most important tests obtained in the last five years on the complete expansion turbine, together with the authority for such tests, are given in Table II.

The efficiency of the turbines as shown in the tables is the ratio of the

$$\frac{\text{Actual useful work done by the turbine.}}{\text{The mechanical equivalent of the heat drop under the operating conditions, due to adiabatic expansion.}}$$

This ratio is commonly known as the Rankine-cycle efficiency. With turbo-generators this efficiency is generally stated by taking the actual energy output at the switchboard in kilowatts, as the numerator of the fraction expressed above, and is consequently less in value than the actual efficiency of the turbine itself, because the efficiency of the generator is less than unity.

When comparing the performance of turbines, the Rankine-cycle efficiency is a more correct basis than the water rates obtained on tests, because if the operating conditions are not similar the comparison of water rates is an unfair one, unless proper correction factors are applied.

Turbines are generally designed for given operating conditions, involving (*a*) quality of steam (superheat), (*b*) pressure, and (*c*) vacuum, and the correction for the change in these operating conditions as applied to a given machine must be taken into account when a comparison of the steam consumption of different machines is made.

Such corrections for steam consumptions should also be divided into two classes: (1) a comparison of turbines designed for different operating conditions, and (2) a comparison of turbines operating under conditions other than those for which they were designed.

For such corrections, standard steam conditions should be assumed to which the performance of all turbines may be reduced by applying proper correction factors.

Such standard conditions as now obtain in this country may be taken as follows:

For high-pressure turbines, 175 pounds pressure per square inch (gauge), 100° F., 28 inches vacuum (referred to 30-inch barometer);

For low-pressure turbines, 16 pounds pressure per square inch (absolute), 0° F. superheat, 28 inches vacuum, (referred to 30-inch barometer).

In Appendix III a list of correction factors is given for application to the general cases and operating conditions met in this country.

These correction factors are of great advantage to prospective purchasers of turbines, in order that they may more intelligently specify those operating conditions which are best suited to the economy of their plant,

FIELD OF APPLICATION OF THE TURBINE.

In the past five years the field of application of the turbine has been wonderfully increased, and the flexibility inherent in its construction has been developed by its adoption to: (1) non-condensing operations, (2) utilization of low-pressure steam, (3) reducing or bleeder turbines, and (4) mixed-pressure turbines.

In general, it may be stated that the distinguishing feature of these applications resolves itself into expansion of steam to and from atmospheric pressure.

Space will not permit a lengthy discussion of the various types of these special cases of the complete expansion turbine, except to say that conditions are arising to continually broaden the field of application of these special machines. Some general considerations of the designs of such machines obtain, however, which may be briefly stated as follows:

NON-CONDENSING TURBINES.

The non-condensing turbine may be made for any given condition, utilizing either the reaction or impulse machine with approximately the same efficiency, except where relatively large

TABLE I.

No.	Maker of turbine	Type	Date of test	Load KW.	R.P.M.	Steam pressure Lbs. Abs.	Super-heat	Vacuum referred to 29.92″ barometer	Pounds of steam per KW.Hr.	Efficiency ratio	Reference
8	Westinghouse Machine Co.	Parsons	1902	1998	1200	170.1	41.56	26.91	19.10	58.0	Purchaser's Test, Hartford Elec. Lt. Co.
84	Westinghouse Machine Co.	Parsons	1905	5694	750	193.2	131.50	27.41	16.20	60.7	Purchaser's Test, Penn. T. & T. Co.
253	Westinghouse Machine Co.	Parsons	1907	9865	750	191.7	96.00	27.31	14.98	67.2	Electrical World, Jan. 29, 1908.
	General Electric Co.......	Curtis	1907	10186	720	190.7	147.00	29.47	12.90	62.1	Electrical World, Jan. 29, 1908.

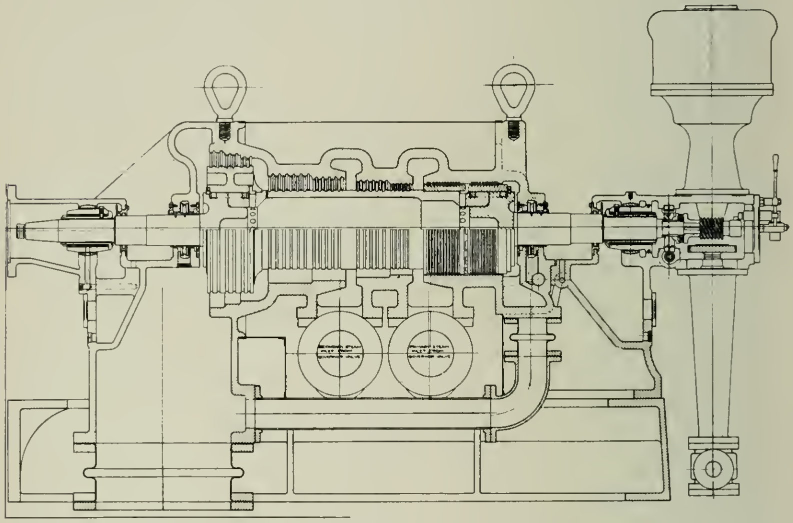
TABLE II.

No.	Maker of turbine	Type	Date of test	Load K.W.	R.P.M.	Steam pressure Lbs. Abs.	Super-heat	Vacuum referred to 29.92″ barometer	Pounds of steam per KW.Hr.	Efficiency ratio	Reference
1	Erste Brunner M.F.G.....	Curtis-Parsons	1910	2128	1500	156.2	120.31	27.89	13.82	71.8	Periodische Mitteilungen.
2	Erste Brunner M.F.G.....	Curtis-Parsons	1910	6000	960	184.9	197.64	28.18	12.56	71.3	Zeit. d. V. D. Ing., 12/10/'10.
3	Erste Brunner M.F.G.....	Curtis-Parsons	1910	7442	960	192.0	205.51	28.18	12.625	70.3	Periodische Mitteilungen.
4	Westinghouse Machine Co.	Curtis-Parsons	1910	9173	1800	181.7	59.07	27.81	14.57	68.9	Trans. A. S. M. E., Vol. 32.
5	Erste Brunner M.F.G.....	Curtis-Parsons	1910	1416	1260	128.2	135.69	27.60	15.18	68.8	Periodische Mitteilungen.
6	Allis-Chalmers...........	Parsons	1908	4300	1800	186.4	107.97	27.96	14.02	68.4	Sibley Jour. of Eng. 1/11/'
7	Richardson & Westgarth..	Parsons	1910	6257	1200	203.7	176.00	29.10	11.90	68.4	Electrician, Vol. 66, p. 862, 1911.
8	General Electric Co.......	Curtis	1912	12460	720	207.5	191.00	27.52	13.63	68.2	Jour. A. S. M. E., Aug. '12, p. 1169.
9	Brown-Boveri & Cie......	Curtis-Parsons	1911	3053	1360	150.2	146.40	29.00	13.01	68.0	Dinglers P. J., 6/17/'11.
10	Brown-Boveri & Cie......	Curtis-Parsons	1911	1750	1500	176.4	214.50	27.08	14.23	67.5	Zeit. f. d. G. Turb., 5/30/'11.

11	James Howden & Son.....	Zoelly	1909	6383	1000	202.7	136.98	27.33	14.305	67.5	Engineer, London, 10/29/'09.
12	M. A. N..................	Zoelly	1910	1400	3000	180.7	180.53	27.40	14.21	67.4	Zeit. d. V. D. Ing., 12/10/'10.
13	Richardson & Westgarth. .	Parsons	1910	5600	1200	203.7	166.00	29.12	12.10	67.3	Electrician, Vol. 66, p. 862, 1911.
14	Westinghouse Machine Co.	Curtis-Parsons	1906	9830	750	192.2	96.43	27.22	15.15	67.0	Trans. A. S. M. E., Vol. 32.
15	British Westinghouse.	Curtis-Rateau	1911	5066	1500	190.2	174.31	28.68	13.00	67.0	Electrical Review, 6/23/'11.
16	Brown-Boveri & Cie......	Curtis-Parsons	1910	3764	1500	161.2	196.78	28.77	13.04	66.8	Zeit. f. d. G. Turb., 5/30/'11.
17	Escher Wyss & Co.......	Zoelly	1910	2052	3000	193.9	205.70	28.39	13.04	66.6	Zeit. f. d. G. Turb., 2/20/'11.
18	General Electric Co.......	Curtis	1907	7526	720	184.4	134.00	28.65	13.732	66.6	Jour. A. S. M. E., Aug. '12, p. 1169.
19	British-Thomson-Houston	Curtis	1911	2987	1500	154.7	144.07	26.75	15.96	66.5	Engineering, 10/20/'11.
20	Bergmann...............	Curtis-Rateau	1909	1545	1500	188.5	204.04	28.59	12.97	66.4	Zeit. d. V. D. Ing., 12/10/'10.
21	Westinghouse Machine Co.	Parsons	1907	9870	750	191.7	95.00	27.25	15.00	66.3	Zeit. d. V. D. Ing., 1907, p. 1782.
22	General Electric Co.......	Curtis	1907	12000	750	200.0	125.00	28.00	14.22	66.2	Jour. A. S. M. E., Aug. '12, p. 1169.
23	Oerlikon..................	Rateau	1911	3166	1500	213.9	275.42	29.25	11.44	66.1	Engineering, 10/20/'10.
24	General Electric Co.......	Curtis	1911	6500	1800	180.0	100.00	28.00	14.78	66.1	Jour. A. S. M. E., Aug. '12, p. 1169.
25	Escher Wyss & Co........	Zoelly	1911	5118	1000	133.7	199.48	27.55	15.18	65.7	Dinglers P. J., 7/15/'11.
26	Bergmann...............	Curtis-Rateau	1910	2477	1500	140.0	168.91	28.81	13.93	65.6	Elict. Zeit.., 4/20/'11.
27	Brown-Boveri & Cie......	Parsons	1903	3500	1360	156.4	137.20	28.84	13.71	65.6	Zeit. d. V. D. Ing., 12/10/'10.
28	Westinghouse Machine Co.	Curtis-Parsons	1909	11466	750	191.7	105.65	28.07	14.45	65.5	Trans. A. S. M. E., Vol. 32.
29	Escher Wyss & Co........	Zoelly	1910	4189	1000	179.7	183.98	28.66	13.30	65.5	Zeit. f. d. G. Turb., 2/20/'11.
30	Richardson & Westgarth. .	Parsons	1910	4256	1200	206.7	162.00	29.19	12.40	65.1	Electrician, Vol. 66, p. 862, 1911.
31	British Westinghouse.....	Curtis-Rateau	1911	2930	1500	210.2	187.90	28.18	13.72	64.9	Electrical Review, 4/28/'11.
32	A. E. G..................	Curtis-Rateau	1908	4239	1500	188.3	285.13	29.11	11.97	64.9	Stodola, 4th ed., p. 404.
33	Escher Wyss & Co........	Zoelly	1911	3540	1500	155.1	107.86	28.21	15.07	64.8	Dinglers P. J., 7/15/'11.
34	F. Ringhoffer............	Zoelly	1908	3000	1000	170.7	101.18	27.60	15.52	64.8	Zeit. d. V. D. Ing., 12/10/'10.
35	Brown-Boveri & Cie......	Parsons	1907	3522	1360	156.9	136.00	28.945	13.70	64.8	Zeit. d. V. D. Ing., 1908, p. 516.
36	Els. Masch. Fabr.........	Zoelly	1910	3500	1500	177.7	142.00	28.435	14.07	64.8	Zeit. d. V. D. Ing., 1910, p. 1500.
37	M. A. N..................	Zoelly	1910	1250	3000	182.1	207.89	28.82	13.09	64.4	Zeit. d. V. D. Ing., 12/10/'10.
38	Brown-Boveri & Cie......	Parsons	1910	3000	1360	165.0	258.91	27.02	14.75	64.3	Die Turbine, 6/20/'11.
39	C. A. Parsons & Co.......	Parsons	1907	5164	1200	214.3	121.26	28.95	13.18	64.3	Stodola, 4th ed., p. 439.
40	British Westinghouse.	Curtis-Rateau	1911	3645	1500	208.3	180.00	27.78	14.03	64.3	Electrical Eng'r, Vol. 47, p. 461, '11.
41	A. E. G..................	Curtis-Rateau	1906	3766	1500	185.2	247.00	28.78	12.80	64.2	Zeit. d. V. D. Ing., 1907, p. 386.
42	Escher Wyss & Co........	Zoelly	1910	1641	3000	221.0	281.63	27.91	13.08	64.1	Zeit. f. d. G. Turb., 2/20/'11.

capacities are demanded, in which case the reaction turbine would have the advantage in efficiency. Since a non-condensing operation would require approximately twice the amount of steam for a given output as would be necessary with a complete expansion turbine, opportunity would be afforded for better proportioning of the reaction blading to give maximum efficiency, and, due to the incomplete expansion, a relatively short spindle would result on account of a smaller number of rows of blades being required to absorb less than half of the total energy drop occurring in a complete expansion machine. A design of such a turbine is illustrated in Fig. 51.

FIG. 51.

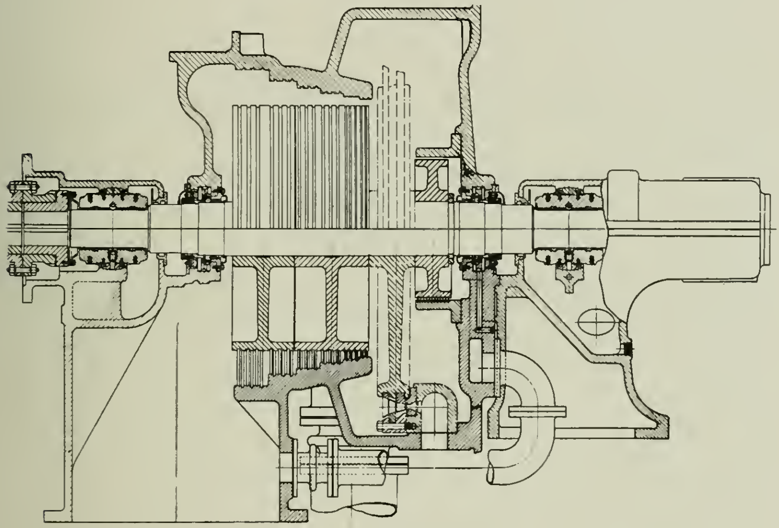


Longitudinal section, 15 N.C., 3600 revolutions per minute, single-flow high-pressure turbine with Kingsbury thrust-bearing.

LOW-PRESSURE TURBINES.

In a low-pressure turbine design, the reaction elements again lend themselves admirably to the efficient extraction of the energy of low-pressure steam, because, for a given output, the blade proportions of the low-pressure turbine would be practically twice the capacity of those required in a single expansion turbine, resulting, as in non-condensing operation, in blade proportions of maximum efficiency, a short, simple construction of the spindle and cylinder, and (with moderate capacity) the elimination of balancing pistons by resorting to the double-flow construction. The same arguments for simplicity would, of course, apply to impulse turbines, but the fact that reaction blading is, in general, best adaptable to the low-pressure portions of any turbine should be a distinct advantage in favor of such a machine in low-pressure work. Figs. 52 and 53 indicate single- and double-flow low-pressure machines as built by The Westinghouse Machine Company.

FIG. 52.



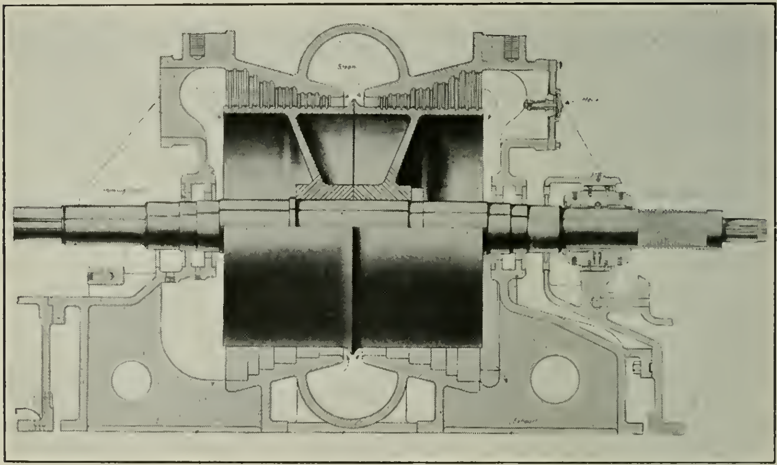
Low-pressure single-flow turbine.

REDUCING OR BLEEDER TURBINES.

Where it is desirable to utilize steam at about atmospheric pressure for heating or industrial purposes, the turbine lends itself admirably to fulfil such a condition. It is extremely simple to bleed steam out of the turbine, at any particular pressure, in quantity proportional to the amount of flow through the turbine. Suitable automatic valves may be applied to the bleeder exhaust of the turbine to maintain (irrespective of the load the turbine may carry) that quantity of steam required to maintain a constant pressure in the bleeder line.

The conditions having been determined as to the amount of steam to be supplied from the turbine, the proportions of the elements beyond the bleeder valve are made to utilize the steam remaining under the operating conditions imposed, thus extracting the maximum amount of energy from the complete expansion of the steam required for generating power, and giving at the same time a constant steam supply at a given pressure (usually about 15 to 20 pounds absolute) for heating or industrial purposes. Likewise, with suitable valve arrangements, steam at relatively low pressures, say 15 pounds absolute, can be bled into the low-pressure portion of the turbine, and the energy from the expansion of such steam to a high vacuum may be utilized in the low-pressure portion of a bleeder turbine for the development of power. The bleeder valves and the initial steam valve, in the high-pressure portion of the turbine, may be governor-controlled and make, therefore, a purely automatic machine, which will take care of variable operating conditions by the governor control. An illustration of such a machine is shown in Fig. 54, where the high-pressure portion is designed with an impulse wheel and the low-pressure portion with reaction blading.

Fig. 53.

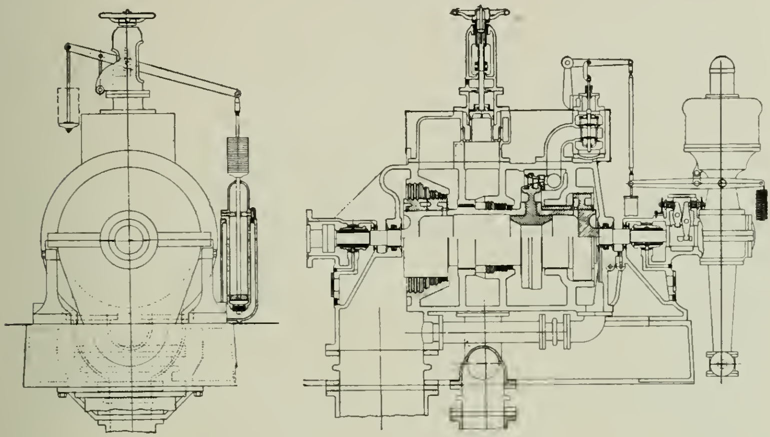


Low-pressure double-flow turbine.

MIXED-PRESSURE TURBINES.

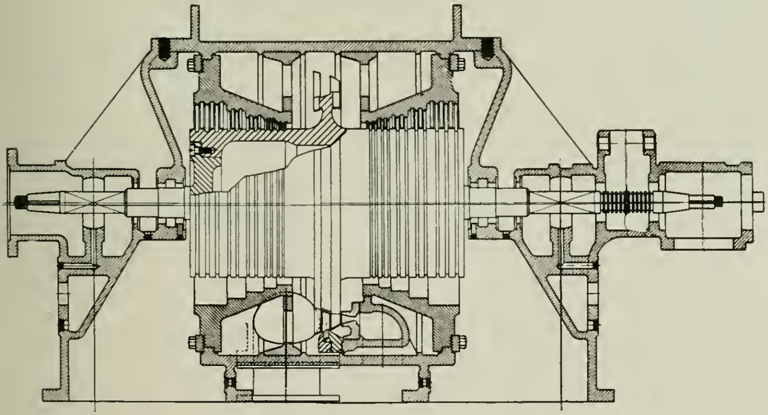
The mixed-pressure turbine is really a modification of conditions requiring a low-pressure turbine. Suppose a source of low-pressure steam being available from which it is desirable to extract the energy in the development of power, and where, at certain times in the operation, sufficient low-pressure steam is not available to generate the amount of power required: To suit this condition, a low-pressure turbine is supplemented by a high-pressure element which can utilize steam at high pressure through complete expansion. When sufficient low-pressure steam is available to furnish the required power, the high-pressure steam is cut off by the governor or by other means, and when the low-pressure steam is not sufficient for the power required,

FIG. 54.



Bleeder turbine assembly.

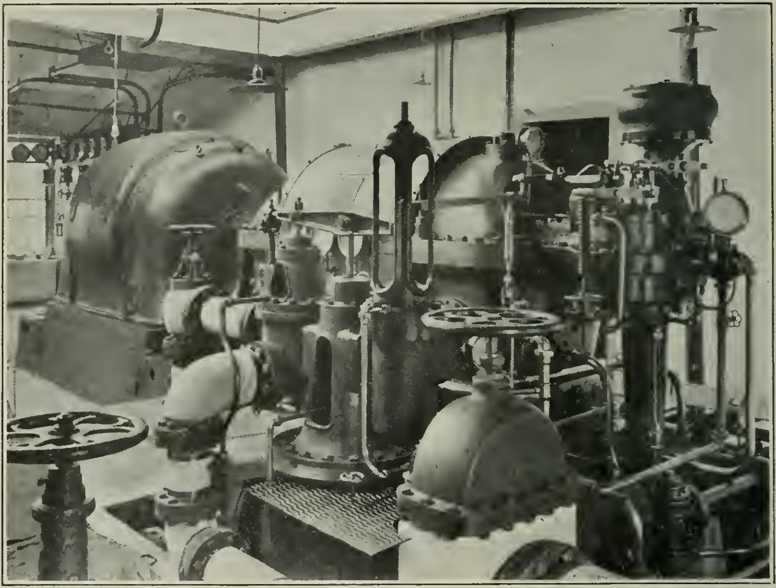
FIG. 55.



Low-pressure turbine with live steam valve.

the governor of the turbine admits steam to the high-pressure element to supplement the low-pressure supply for the development of the power required. This same arrangement can be accomplished with the low-pressure turbine by applying a high-pressure valve admitting steam into the low-pressure line direct. Figs. 55 and 56 illustrate machines of this construction, and the desirability of either type depends entirely on the operating conditions imposed.

FIG. 56.



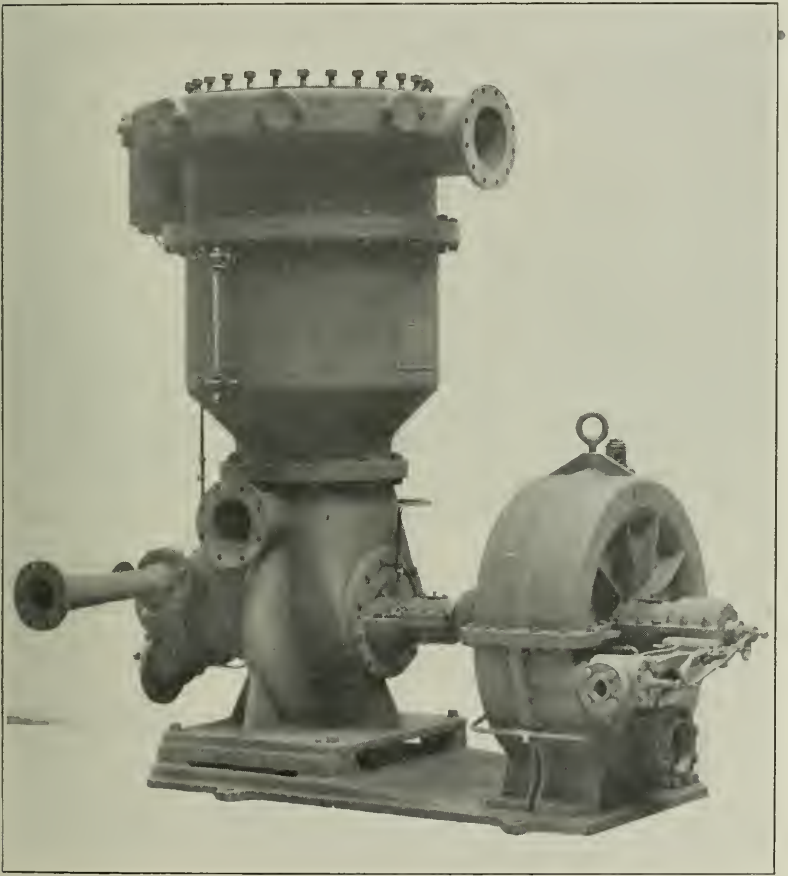
Low-pressure turbine with live steam valve, installed at Peace Dale Manufacturing Company, Peace Dale, R. I.

RECENT MISCELLANEOUS TURBINE APPLICATIONS.

Due to the recent development of small turbines of relatively low rotative speeds that have recently come into quite extended use for driving auxiliaries in power plants and for other applications, apparatus which formerly was operated by reciprocating means has been developed for rotary drive with marked reduction in the cost, weight, space occupied, and efficiency obtained.

Perhaps the best example of this development has been the commercial introduction of the Westinghouse-Leblanc condenser, which, by the introduction of a rotary vacuum pump, permits the driving of the condenser circulating and air pumps by direct connection to a small turbine unit, as illustrated in Fig. 57.

FIG. 57.



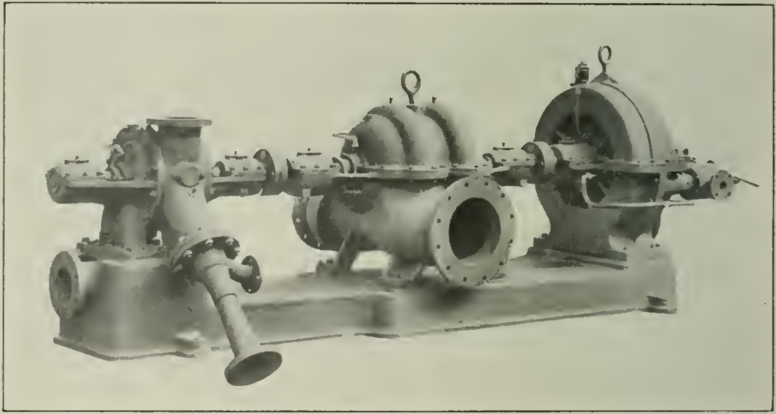
Turbine-driven type E high-speed condenser.

The application of the small turbine to the field of centrifugal pumps is rapidly replacing the reciprocating engine, the advantages of the turbine being due to the fact that for low lift pumps and high-pressure pumps the speed for the best design is beyond that suitable for direct connection to a reciprocating engine.

Fig. 58 is an application of the small turbine to a centrifugal circulating and Leblanc air pump for surface condensers. Fig. 59 illustrates a boiler feed centrifugal pump direct connected to a small Westinghouse turbine. Similarly, the small turbine is admirably adapted to the driving of centrifugal blowers, an example of which is illustrated in Fig. 60.

As auxiliary apparatus for large power stations, or in places where it is important to reduce attendance to a minimum and where reliability is essential, the small direct-current turbo-generator unit is now generally accepted in place of the reciprocating engine, direct-connected or belt-driven apparatus, principally on account of its reduced size and cost, and the many advantages incident to rotary apparatus. Fig. 61 represents several sizes of these machines, from 1 kilowatt up, as manufactured by The Westinghouse Machine Company, both in direct- and alternating-current sets.

FIG. 58.



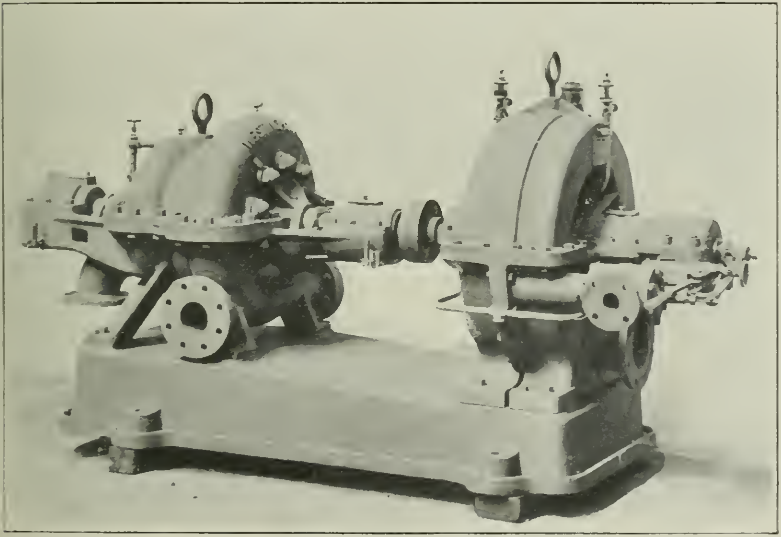
Air and circulating pump unit for 2000 square feet surface condenser, built for Louisville & Nashville Railway Company.

APPLICATION TO MARINE SERVICE.

The application of the turbine to marine propulsion is perhaps the broadest single field for the utilization of maximum horsepower output. Until within the last few years this field was limited to approximately 5 per cent. of the total merchant marine vessels, on account of the difficulty of correlating the high speed of the turbine and the relatively low speed of the ship's propeller.

It has been, of course, possible to apply turbines to the slower speed ships, but it has not been practicable to do so, because there would have been no saving in weight, space, or economy over the reciprocating engine, since the turbine is essentially a machine of relatively high rotative speeds for efficient operation, while the screw propeller requires relatively low speed of rotation.

FIG. 59.

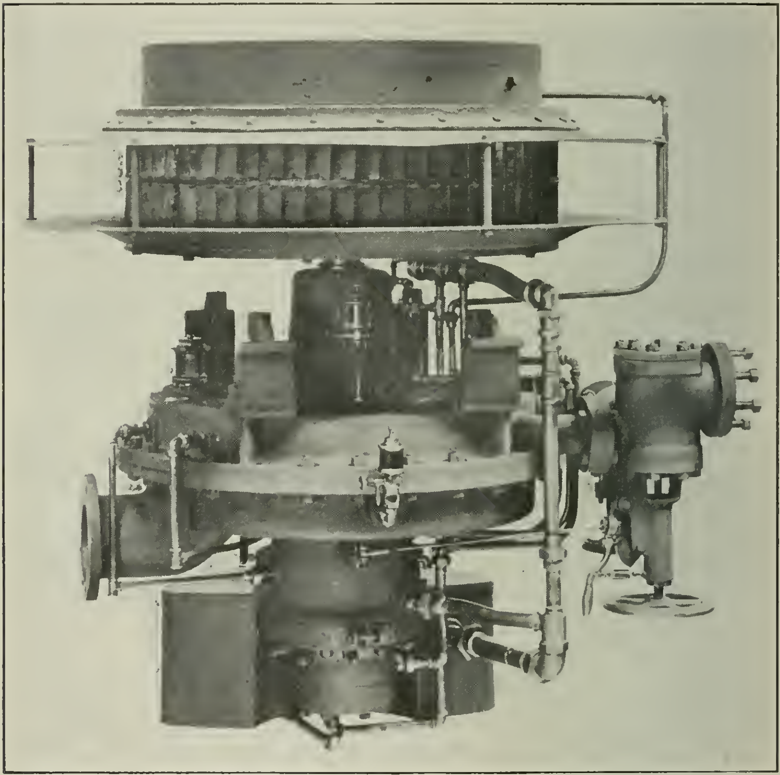


Small turbine driving boiler-feed pump.

Recognizing the possibilities of the steam turbine for marine propulsion, Mr. George Westinghouse, in 1903, commissioned the late Rear Admiral George W. Melville, Ex-Engineer-in-Chief of the United States Navy, and Mr. John H. Macalpine, Consulting Engineer, to make an impartial investigation and report on the status of the marine steam turbine.

This report, a number of copies of which were printed for private circulation in May, 1904, did not indicate that the reciprocating engine would be immediately superseded by the steam turbine, as it was then being applied to marine propulsion, but concluded with the statement that: "If one could devise a means for reconciling in a practical manner the necessarily high speed of the turbine with the comparatively low rate of revolution required by an efficient propeller, the problem would be solved and the turbine would practically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of great genius."

Fig. 60.

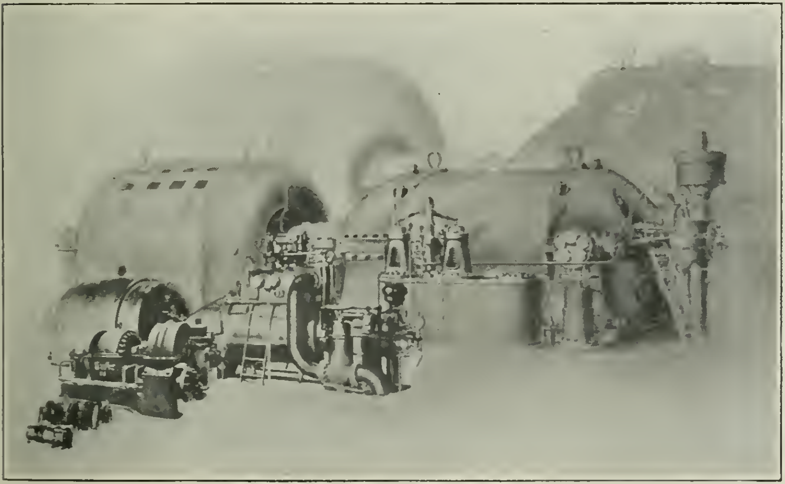


06 V.N.C turbine with 39-inch 25,000 cubic foot Navy type blower.

Acting on this suggestion, Mr. Westinghouse caused designs to be made for a reduction gear for large power transmission, which was constructed and tested in the works of The Westinghouse Machine Company at East Pittsburgh, after designs of Messrs. Melville and Macalpine embodying a floating frame carrying the pinion, which had been shown mathematically to be necessary to the successful operation of high-speed gearing transmitting large powers.

This experimental gear transmitted under test 6800 horsepower with a pinion speed of 1500 revolutions per minute and a gear speed of 300 revolutions per minute. These tests demonstrated conclusively that the floating frame would insure correct alignment of the gear teeth, which is absolutely essential to the transmission of large powers. It was believed that this particular design was more rigid than desirable, because the connection between the floating frame and the casing was a metallic one, and in consequence noise and vibration were not eliminated to the degree that it was believed to be possible.

FIG. 61.



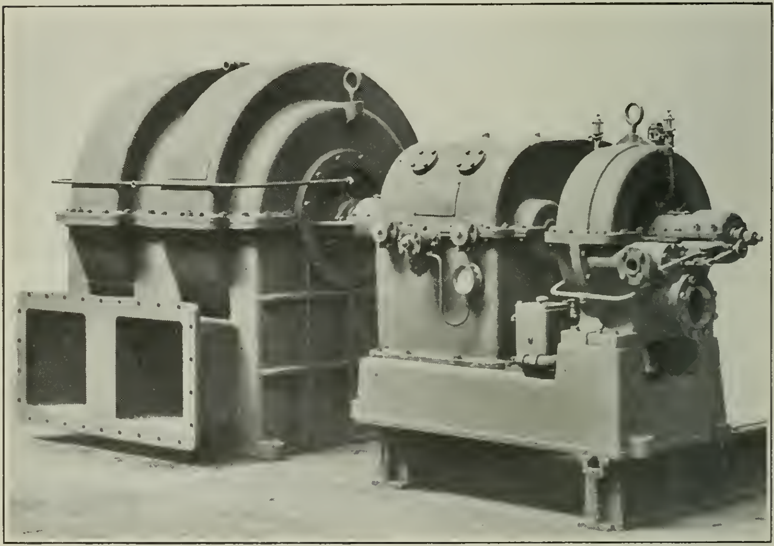
1-kilowatt to 10,000-kilowatt turbines.

As a substitute, therefore, for the Melville-Macalpine design, Mr. Westinghouse devised a hydraulically supported pinion frame having a degree of flexibility in itself, and which was supported on the main frame by oil in the hydraulic cylinders in the floating frame. This construction also allowed vertical movements of the pinion and floating frame, which were impossible in the Melville-Macalpine design.

A test on a large scale of the Westinghouse floating frame demonstrated that this accomplished all the objects of the original inventors, and, by reason of the absence of metallic connection between the pinion frame and the casing, the noise and vibration incident to the operation of the gear were almost wholly eliminated.

The tests on this large experimental gear aroused great interest in naval and merchant marine circles, and resulted in the application of turbine gearing sets of 3600 horsepower each to the twin screw U. S. S. *Neptune,* and the general application of turbine gearing to the larger sizes of direct-current generators, centrifugal pumps, rolling-mill machinery, etc. A complete technical description of the experimental reduction gear and machinery in the U. S. S. *Neptune* may be found in London *Engineering* of September 17, 1909, and November 17, 1911, respectively.

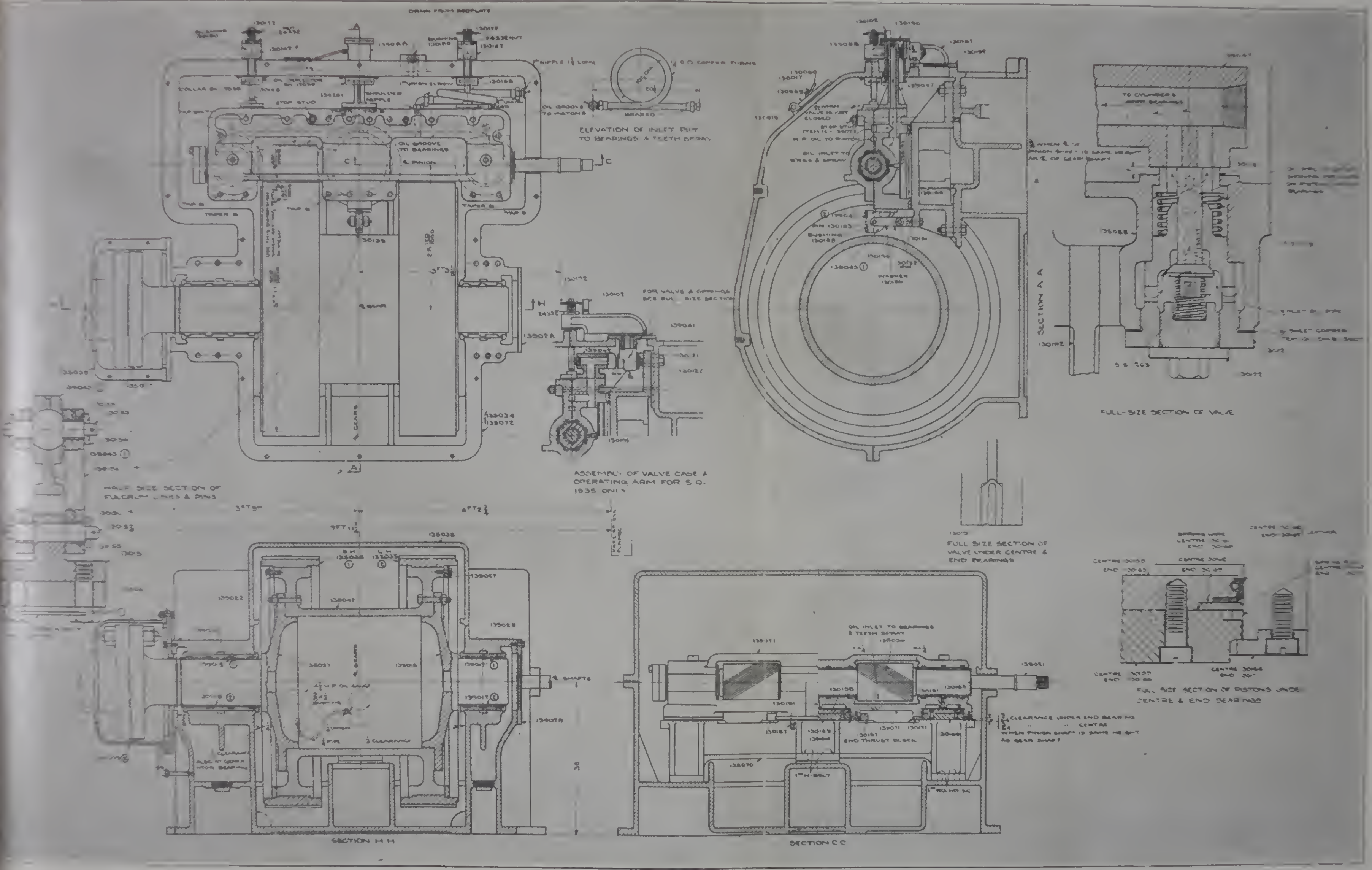
FIG. 63.



25,000 G.P.M. circulating pump, reduction gear and turbine drive. Built for Edison Electric Illuminating Company, Brooklyn, N. Y.

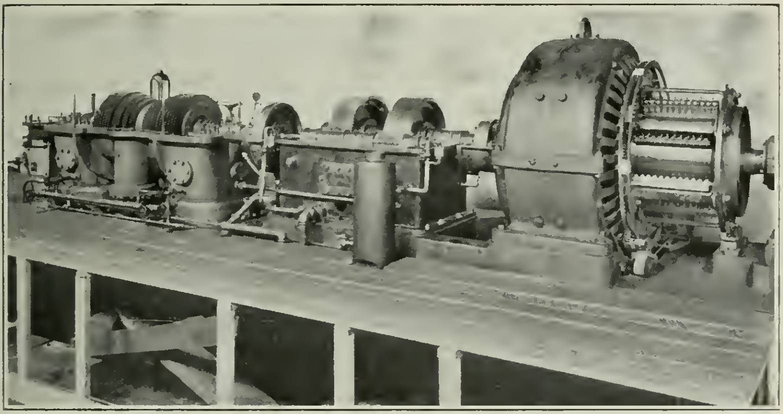
Twenty-one sets of the Westinghouse turbine reduction gearing have been constructed and installed by The Westinghouse Machine Company with eminently satisfactory results in opera-

FIG. 62.


DRAWN FROM BEDPLATE
NIPPLE 1½ LONG
½ O.D. COPPER TUBING
OIL GROOVE TO PISTON B
BRAZED
ELEVATION OF INLET PIPE TO BEARINGS & TEETH SPRAY
C
H
A
OIL GROOVE (TO BEARINGS)
℄ PINION
℄ GEAR
STOP STUD
TAPER B
FOR VALVE & OPENINGS SEE FULL SIZE SECTION
ASSEMBLY OF VALVE CASE & OPERATING ARM FOR S.O. 1535 ONLY
HALF SIZE SECTION OF FULCRUM LINKS & PINS
SECTION A A
WASHER
BUSHING
TO CYLINDERS & INNER BEARINGS
FULL-SIZE SECTION OF VALVE
FULL SIZE SECTION OF VALVE UNDER CENTRE & END BEARINGS
FULL SIZE SECTION OF PISTONS UNDER CENTRE & END BEARINGS
SPRING WIRE
CENTRE
END
OIL INLET TO BEARINGS & TEETH SPRAY
CLEARANCE UNDER END BEARING
CENTRE
WHEN PINION SHAFT IS SAME HE'GHT AS GEAR SHAFT
END THRUST BLOCK
1" H. BOLT
℄ SHAFTS
℄ GEARS
CLEARANCE
SECTION H H
SECTION C C

tion. A recent report made of the installations with direct-current generators ranging from 1000 to 2000 horsepower transmission gives the interesting figures shown in Table III, together with the statement that no appreciable wear is evident on the teeth of any of these gears. The distinctive feature of the Westinghouse gears which are of the double helicoidal type is the flexible or self-aligning quality of the pinion shaft, which, with its frame and bearings, is hydraulically supported in such a manner as to equalize and distribute the tooth pressure evenly, resulting in smooth and quiet running without the necessity of grinding the teeth or of exercising that extreme care and accuracy in alignment of the pinion bearings which are so essential in a gear of large size. Fig. 62 illustrates the general construction of one of these gears as applied to direct-current generators where the speed of rotation is in one direction only. Fig. 63 illustrates the application of reduction gearing to turbine-driven centrifugal pumps, and Fig. 64 its application to the operation of direct-current generators. Fig. 65 illustrates the construction of the most recent design of marine reduction gearing where the rotation of the pinion is required for either direction. In these figures the construction of the floating frame and its pistons is readily observed.

FIG. 64.



500-kilowatt turbine, 1000 horsepower reduction gear and D.C. generator (covers removed) (turbine 3600 revolutions per minute, gear 720 revolutions per minute). Built for the Commonwealth Steel Company, Granite City, Ill.

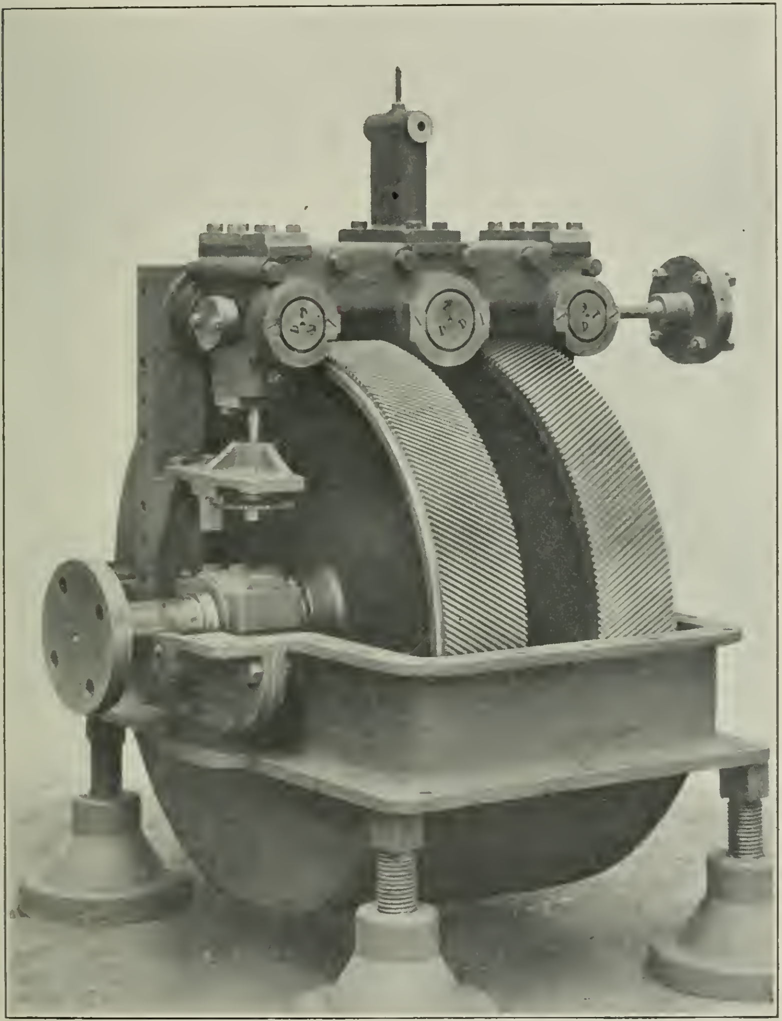
The supporting of the pinion frame hydraulically incidentally

TABLE III.

	Chrome Steel Works.	Commonwealth Steel Co.	Walpole Rubber Company.	San Diego E. L. & P. Co., Cal.	N. Y., N. H. & H. R. R.	Aluminum Co. of America.	Colorado Portland Cement Co.
Number of hours run..	4,500	7,500	6,220	6,132	4,166	2,000	8,500
Diameter of pinion....	5½	5½	5½	7	7	5½	7
Revolutions per minute pinion..............	3,600	3,600	3,600	3,600	3,600	3,600	3,600
Total number of revolutions.............	972,000,000	1,620,000,000	1,340,000,000	1,320,000,000	900,000,000	432,000,000	1,840,000,000
Horsepower maximum.	1,000	1,000	1,000	2,000	2,000	1,000	2,000
Horsepower per pinion, average.............	370	770	about 700	880	1,200	480	1,175
Gear ratio............	1 to 5	1 to 5	1 to 5	1 to 7	1 to 7	1 to 5	1 to 7
Width of gear face	17.5″	17.5″	17.5″	22″	22″	17.5″	22″
Number of teeth per pinion..............	31	31	31	32	32	31	32
Pinion material.......	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.
Gear material........	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.	Mild steel. .30 to .40 carbon.

gives a very accurate dynamometer, since the hydraulic pressure supporting the frame is proportional to the load carried; and with the knowledge of the speed of rotation, the area of the pistons supporting the pinion frame, and the hydraulic pressure, the horsepower transmitted is readily computed without the aid of special or delicate instruments, or expert observers.

FIG. 65.



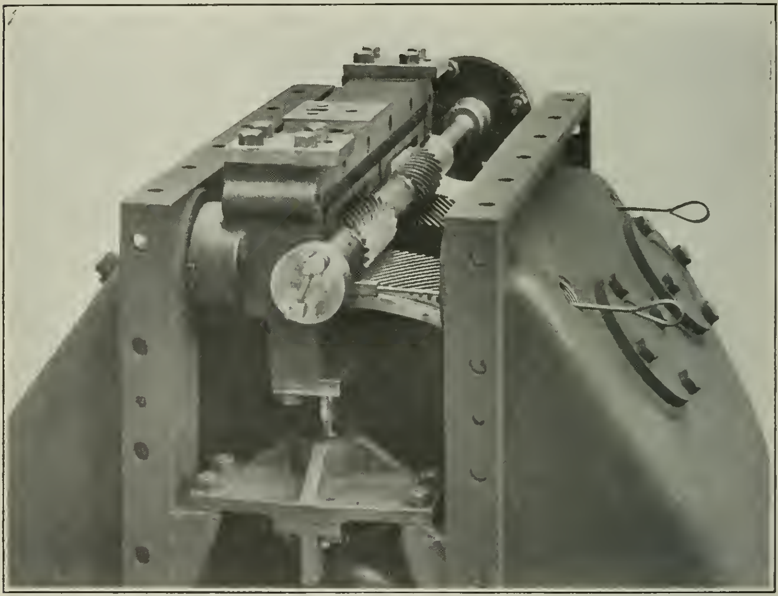
Marine reduction gear. Part of cover removed.

This dynamometer feature should be of great service in marine work where it is very desirable to obtain the horsepower delivered to the propeller shaft.

The application of the turbine itself to marine work is a different kind of a problem than to driving electrical apparatus, for the reason that in the former case a variable speed is required, while in the latter case a constant speed is required.

In the majority of cases, after a ship is under way, the speed may be considered as constant. In naval vessels, however, it is generally desirable to have a cruising speed, approximately one-half of the full speed. This involves a compromise in the turbine design to give relatively high economy for cruising at a propeller speed of approximately one-half that of full speed, and a power output of approximately one-eighth to one-tenth that required at full speed.

FIG. 65A.



Marine reduction gear. Showing floating frame and pistons.

As has been pointed out previously in this paper, the efficiency of turbines increases with the power and decreases as the blade speed decreases, with the same pressure drop.

While the introduction of gearing very materially adds to the ease of design and construction of marine turbines and to their increased economy, due to the high rotative speeds, and on account of the better blading proportions, yet both theory and practice require a very different blading for marine operation than for land service with constant speed, especially where cruising speeds in marine service are desirable.

Fig. 50 shows that the efficiency of any blading diminishes as the velocity ratio diminishes or increases, beyond a certain velocity ratio which gives maximum efficiency.

Irrespective, therefore, of the diminution in power at cruising speed, the fact that the speed of rotation of the turbine is reduced one-half would, with the same energy drop, result in a very marked decrease in efficiency. If, however, the turbine be over-bladed, a reduction in the speed of rotation over that obtaining at full power will still give a high efficiency,—and the widest range in this respect, as illustrated in Fig. 50, may be obtained with reaction blading rather than pure Curtis or pure Rateau elements.

If, however, a combination impulse reaction turbine is employed for marine service, and the blading proportions are properly relegated in the impulse and reaction sections, one to the other, the reduction in efficiency in either may be offset by an increase in efficiency in the other, and consequently a more uniform water rate or efficiency may be obtained over wide ranges of speed and power. Also, the remarks already made in connection with the advantages of the combination impulse reaction turbine for electric drive hold good for the application of the turbine to naval or merchant vessels, and for these reasons it is believed that this type will predominate in the future construction of marine installations.

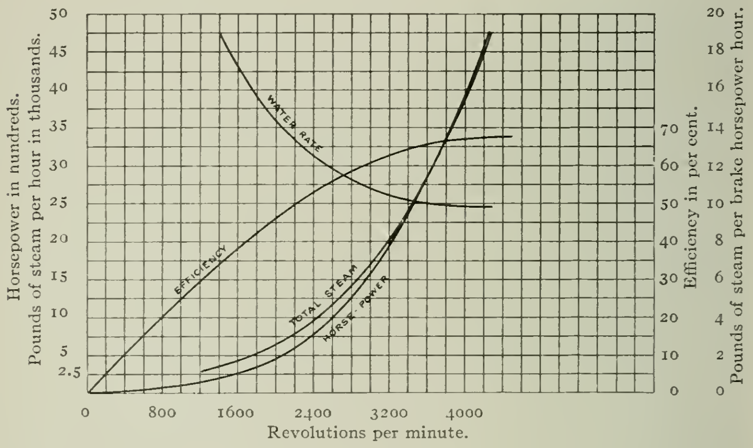
Since the availability of the Westinghouse reduction gear to marine application has been demonstrated, a great deal of experimental work has been instituted and put in progress by Mr. Westinghouse to determine experimentally those features of turbine operation and design which are essential for high economy in the propulsion of naval vessels by means of a turbine and its reduction gearing. These experiments have progressed sufficiently far to warrant the statement made above in connection with the use of the Westinghouse impulse reaction turbine.

Fig. 66 illustrates tests made at variable speeds and powers on a standard commercial Westinghouse impulse reaction turbine designed for turbo-generator work.

There can be no doubt that with a variation in the blading proportion of this machine suitable for marine work the efficiency and water rate curves can be materially flattened and bettered.

The author regrets that at this time he is not in a position to report more fully on what can be accomplished for the betterment of steam consumption in marine propulsion, but from the investigations now under way at the plant of The Westinghouse Machine Company and the development of the turbine and reduction gear as it has rapidly progressed, these will eventually eliminate the reciprocating engine from the field of marine propulsion, as the turbo-generator has effectually eliminated the reciprocating engine driven generator from power station use. As far as the investigations have now progressed it seems entirely practicable to reduce the economy of the reciprocating engines of the battleship *Delaware* 30 per cent. at full speed and 25 per cent. at cruising speed.

FIG. 66.



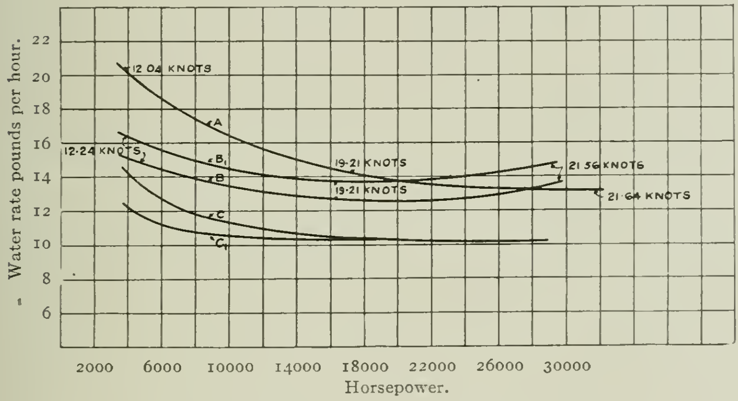
Turbine No. 2190. Variable speed with nozzle control. Reduced to basis of 388 available B.T.U.
265 pounds absolute high pressure inlet, 60° F. superheat, 28.5 inches vacuum. Ratio of speed to power deduced from trials of *North Dakota*.

Fig. 67 illustrates a set of water rate curves of the main propelling machinery of a battleship.

Curve *A* represents the water rate based on shaft horsepower obtained on the Government acceptance trials of the U. S. battleship *North Dakota,* equipped with Curtis turbines; Curve B the results based on the indicated horsepower of the trials of the U. S. battleship *Delaware,* equipped with reciprocating engines; and Curve C the results based on the shaft horsepower which could be obtained by the installation of Westinghouse turbines and reduction gears, in which the turbine efficiency is taken from the tests of a commercial Westinghouse impulse reaction turbine designed for turbo-generator work.

Curve C_1 in Fig. 67 represents the water rate which could be obtained with the use of two independent turbines geared to one propeller shaft, since it is obvious that at cruising speeds one of these turbines could develop the cruising power with better efficiency than if both were operated, or better than if one turbine alone drove through gearing the propeller shaft, for the reason that instead of developing, say, one-tenth of the full power, as would be necessary in a single turbine, one unit of the double turbine arrangement would develop one-fifth full power at cruising speed.

FIG. 67.



A . *North Dakota*, Curtis turbines, water rate per S.H.P.
B . *Delaware*, Reciprocating engines, water rate per I.H.P.
B_1. *Delaware*, water rate per equivalent S.H.P.
C . Westinghouse geared turbines, water rate per S.H.P.
C_1. Westinghouse twin-geared turbines, water rate per S.H.P.

The geared turbine not only results in a very material reduction in the water rate, and consequently the coal consumption, of a ship, but other advantages lie in the saving which may be effected in weight and space. The comparative figures for battleships of the *Delaware* and *Oklahoma* class indicate that the saving in the length of machinery space would amount to 23 per cent. for the former and 30 per cent. for the latter, while the saving in weight would amount to 20 and 21 per cent. respectively.

The application to the merchant marine indicates a saving in space of 40 per cent., a saving in weight of 50 per cent., and a reduction in steam consumption of 30 per cent.

With high-speed turbine and reduction gear installations, other advantages occur, as for instance in the method of control of the engines, which allows, by a simple reliable apparatus, the operation of the turbines from the bridge or any part of the ship.

The following is quoted from an article by Lieut. W. W. Smith, U. S. N., appearing in the August number of the *Journal of the American Society of Naval Engineers,* together with the illustrations, Plates I, II, and III:

"The turbines can be handled in the engine room or from the bridge, both operating stations being essentially the same. It makes no difference which station is used, as the turbines respond exactly the same to the bridge operator as they do to the engineer. Both use the same system, but control it from different places. There could be three or even more operating stations if desirable. In a battleship, for example, a third station could be located in the central station of the ship.

"Operating the turbines in the engine-room is much easier than with the usual types of turbine and engine-operating gear. There are two small levers, one for each turbine, which are operated by one man without difficulty. These two levers automatically control all of the necessary functions with a rapidity and precision which is impossible with manual control. The three principal functions controlled by the operating levers are reversing, regulation of speed, and nozzle control. The regulation of speed refers to the actual revolutions per minute the operator desires, and not the fixed opening of a valve, which only serves as the means for the operator to do this.

"Due to the action of the mechanism, reversals and changes of speed are very rapid, for when the operating lever is moved from one position to another the mechanism automatically opens

Plate I.

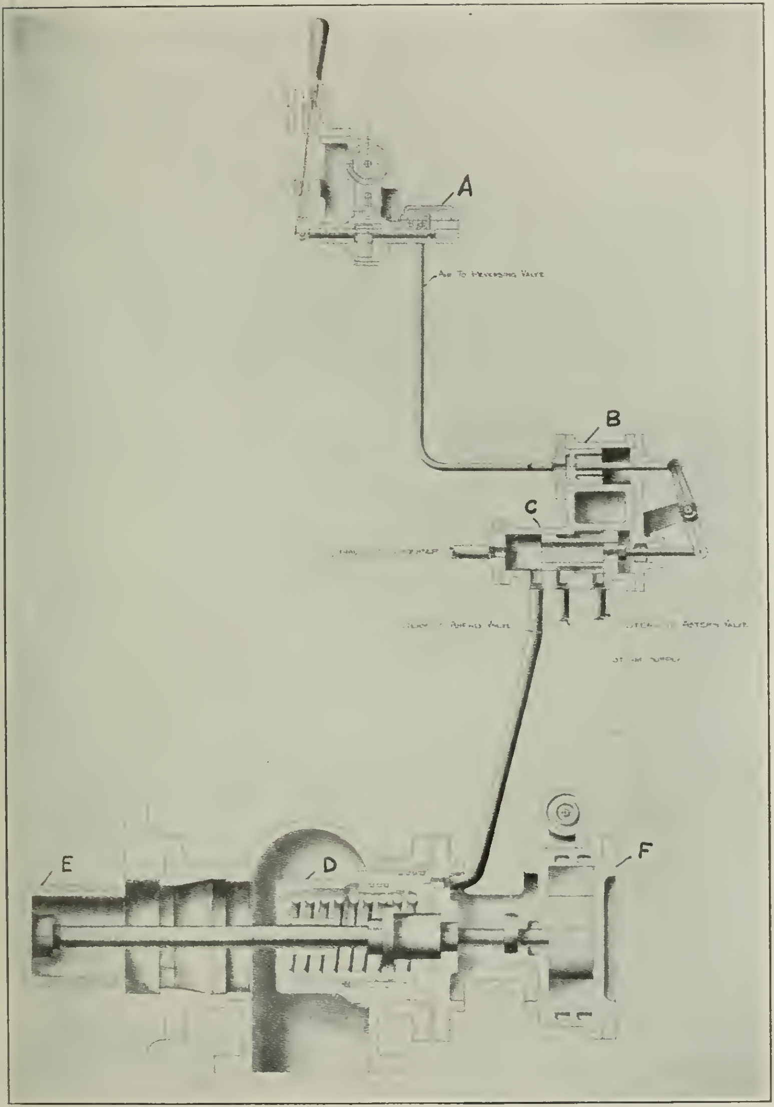


Diagram of Bridge-control Mechanism, Showing the Parts Used for Reversing.

A is the air-reverse valve of the control valve. *B* is the air-operating cylinder of the steam-reverse valve. *C* is the steam-reverse valve. *D*. is the turbine-operating or poppet valve. *E* is the nozzle control valve; *F*, its hydraulic-operating cylinder. *E* and *F* are not used in causing reversal.

wide or closes completely the turbine-inlet valve, which remains so until the exact speed for which the lever is set is attained. This feature of rapid response of the turbines is of importance, because it causes the ship to respond in the minimum of time. This action is always the same. It gives the ship uniform handling qualities, and, what is more important, it can be depended on in an emergency.

PLATE II.

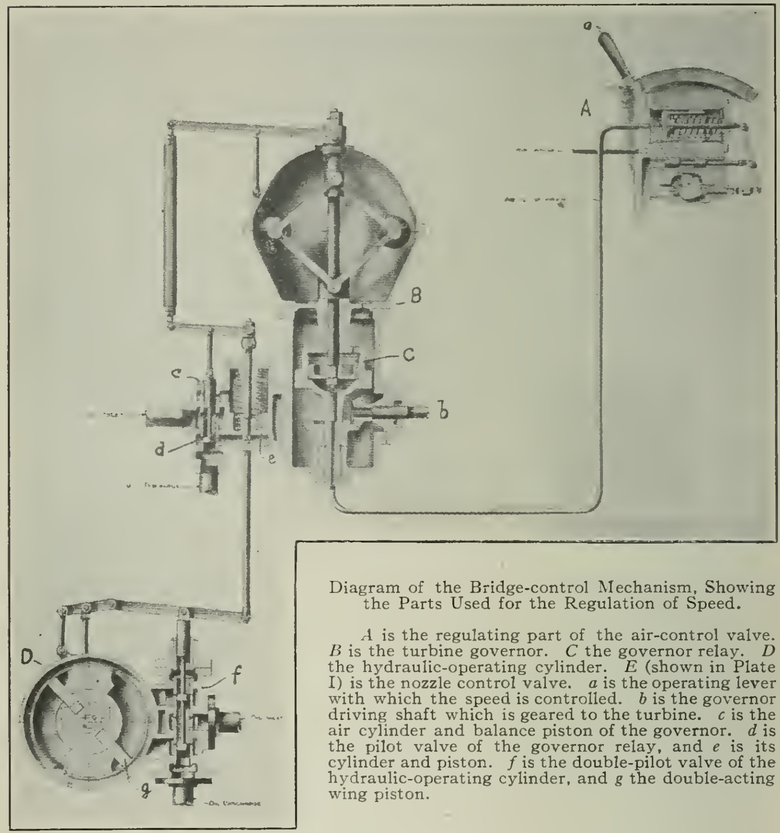
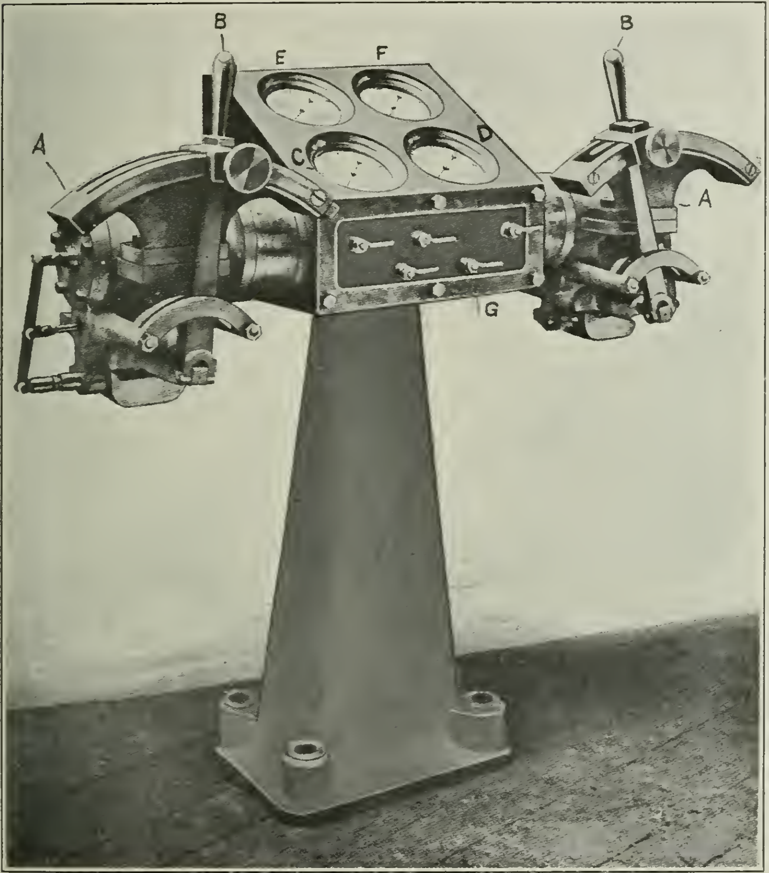


Diagram of the Bridge-control Mechanism, Showing the Parts Used for the Regulation of Speed.

A is the regulating part of the air-control valve. *B* is the turbine governor. *C* the governor relay. *D* the hydraulic-operating cylinder. *E* (shown in Plate I) is the nozzle control valve. *a* is the operating lever with which the speed is controlled. *b* is the governor driving shaft which is geared to the turbine. *c* is the air cylinder and balance piston of the governor. *d* is the pilot valve of the governor relay, and *e* is its cylinder and piston. *f* is the double-pilot valve of the hydraulic-operating cylinder, and *g* the double-acting wing piston.

" When the operating lever is set for a certain speed the turbine comes up to this exact speed, and it is maintained automatically. This is true under all conditions, regardless of steam pressure, vacuum, propeller resistance, etc., provided the speed is not too great,—*i.e.*, below the maximum possible under the condition. This feature makes the operation easy and precise. There is no guesswork as to speed and no revolutions to be counted while manœuvring. This is a valuable feature for either bridge or engine-room operation. It makes

PLATE III.



The Bridge Stand Showing the Air-control Valves A for Both Turbines.

Regulation of speed and reversal are controlled by the operating levers *B*. *C* is the main steam-pressure gauge. *D* the air-reservoir pressure. *E* and *F* are indicators showing the governor air pressure and the revolutions of the propellers. *G* are cut-out cocks for shutting off the control valves, as for connecting both turbines to one valve so as to obtain exactly the same speed on both turbines. This stand is located on the bridge and is used in the same manner as the usual mechanical telegraphs. The control valves are connected with the engine room by ¼-inch pipes as shown in Plate II. The engine-room operating stand is practically the same as the one on the bridge, the pipes being connected in parallel through a single-lever operated cut-out valve.

it possible for one man to do what several are required to do with the usual operating gears, and it is done better.

" While steaming, the operating lever is set for the required speed, which is maintained as noted above. It is not necessary for the engineer to stand by the throttle and constantly to regulate the speed. In effect, the human governor is replaced by a mechanical one which is more accurate and better. The engineer of the watch is free to go about the engine-room and see that the machinery is running properly. All that is necessary is that he or some one on watch be near enough to the operating station to answer a signal promptly. This is true when operating from either station. Compare this mechanical regulation with the method employed on naval vessels steaming in formation. Two men, at least, constantly timing and adjusting the revolutions, and nothing else. These two men could be removed entirely or used to better advantage superintending the machinery, which is usually left to less experienced men. The advantage of mechanical regulation is obvious. This feature of the control system is important, and, even if the engines were operated from the engine-room only, would render it desirable.

" In two instances it was necessary to make reverse speed to avoid collision. The steam pressure dropped very low and some of the auxiliaries were about to stop. The engineer protested vigorously against such unwise operation. He, not knowing the danger, would probably have eased up to save steam, and collision would have resulted.

" During one voyage the propellers came out of water so that excessive racing would have occurred with ordinary machinery. Most of the time they came half way out, and frequently they came practically all the way out. Due to the action of the governing mechanism, racing was prevented. The speed increased and decreased slightly—about 4 per cent. estimated. The turbine-inlet valves were opening and closing continuously, and at times they were entirely closed. Quick-operating valves are necessary effectively to prevent racing. This feature of the control system is of importance, because it will enable a vessel to steam at considerable speed in heavy weather."

The bridge control mechanism as applied to the *Neptune* has since been thoroughly revised and modified in a manner to materially facilitate the accuracy and reliability of operation. An experimental marine turbine and reduction gear has just been erected at the plant of The Westinghouse Machine Company which embodies all features incidental to the recent developments in the Westinghouse marine turbine and reduction gear and the bridge control apparatus. It is believed that this machine will be in operation and open to inspection to those interested in the matter in the course of thirty days, after which time there will doubtless be a thorough technical description of the new features involved.

The thanks of the author are due to The Westinghouse Machine Company for the preparation of the illustrations, to the text-book on steam turbines by Professor Moyer, from which Fig. 17 is taken, and whose outline of the elementary principles of blading has been more or less followed, and to Mr. K. Baumann, of the British Westinghouse Company, from whose paper have been taken almost entirely the correction tables compiled in Appendix III.

(To be continued by Appendices I, II, and III.)

Cause of Dark-colored Nickel Deposits. ANON. (*Brass World*, ix, 1, 27.)—There are several causes of a dark nickel deposit. (1) From too strong current. (2) From the solution becoming alkaline. The articles, if they are of such a shape as to have pockets, carry potash or soda from the cleaning kettle into the nickel-plating bath, if they are not thoroughly removed by rinsing. (3) Stoppage of current. (4) Copper in the nickel solution, arising from articles falling to the bottom of the tank, or from copper in the nickel anodes, or from the copper-plating solution left on the articles to be nickel-plated. (5) Zinc in the nickel solution. (6) Arsenic from impure nickel. The solution should always be slightly acidified with boric acid.

Volcanic Dust in the Atmosphere. ANON. (*Sci. Amer.*, cvii, No. 23, 477.)—Reports of an unusual turbidity of the atmosphere, beginning early last summer, come from various points in Europe and America. There is a marked diminution of the intensity of solar radiation, abnormal displacement of the neutral points of atmospheric polarization, a hazy appearance of the sky, and the presence of Bishop's ring around the sun. There seems reason to attribute these phenomena to the presence in the upper atmosphere of an immense pall of dust arising from the explosive eruption of Katmai volcano, in Alaska, last June.

Case-hardening of Special Steels. A. SAUVEUR and G. A. REINHARDT. (*Trans. Amer. Inst. Min. Eng.,* 1912, 1335.)—Starting with pearlitic steel, by increasing the carbon content or the nickel content, or both, the metal becomes martensitic and eventually austenitic, and remains so after slow cooling,—*i.e.,* it is self-hardening. It should therefore be possible to manufacture case-hardened objects of nickel-steel and of some other special steels having pearlitic,—*i.e.,* soft and tough,—cores, and martensitic or austenitic cases, without quenching. A number of tests made showed the practicability of producing martensitic cases, and, in presence of sufficient nickel, even austenitic cases. Micrographic examination clearly shows the results obtained. An obvious application is the production of tough pieces of machinery with hard wearing surfaces without the distortions and strains produced by quenching.

Band Spectra of Aluminium, Cadmium, and Zinc. EMILY E. HOWSON. (*Astrophysical Journal,* xxxvi, 4, 286.)—The spectra of sun-spots contain many lines and bands which are absent in the spectra of the chromosphere. For instance, the band spectra of *Ca* and *Mg,* often attributed to "hydrides" of these elements, appear strongly in sun-spot spectra. These bands have also been found in the electric arc *in vacuo,* using rods of these elements for the electrodes. Miss Howson has found similar bands in *Al, Cd,* and *Zn* arcs burning under reduced pressure. These bands are not present in the arc in air. The wave-lengths of the lines composing these bands were carefully measured and were found to be expressible by a formula of the type $\lambda_{m} = a+bn+cm_2+dm^3$, where a, b, c, and d are constants for a band and m an integer representing the number of the line in the series. It will be interesting to see whether or not these bands occur in sun-spot spectra and also if they are true metallic radiations or come from hydrogen compounds of the elements.

Effect of Tension on Metals. HANRIOT. (*Comptes Rendus,* clv, 971.)—The ordinary method of determining the hardness of a metal gives only very imperfect knowledge of its general physical condition, since the latter is altered by the pressure of the sphere in the determination. It was therefore attempted—using sliver, brass, and aluminum—to decide whether tensile tests will give a more reliable figure. It is found, however, that the tension itself produces a hardening effect on soft metals and a softening effect on hard metals. The softer specimens show practically the same load at fracture and the same elongation, and the general effect of the tensile strain is to determine in the metal a certain degree of toughness. The effect does not manifest itself immediately the load is applied, but only appears when permanent deformation occurs.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

ANEROID BAROMETERS.

The annual Report of the Director of the Bureau of Standards, just published, contains the following statement concerning the Bureau's investigations of aneroid barometers:

Aneroid barometers are instruments of great importance to surveyors, explorers, aviators, and in scientific investigations. The Bureau has undertaken the thorough study of these instruments, which are used to measure the atmospheric pressure and from this to ascertain the altitude above or below sea level. The investigation, which included the intercomparison of a large collection of aneroid barometers representing twelve different makers, was completed during the year. The results show to what extent the errors of an aneroid are physically inherent and to what extent they may be avoided by suitable tests. In the investigation four kinds of tests were made,—namely, mechanical, temperature, atmospheric, and air-pump tests.

The mechanical tests consisted (1) in determining for each aneroid the probable error of a single pointer reading as affected by parallax, tapping, etc., and (2) in calibrating the pressure and altitude scales of typical aneroids.

The temperature tests consisted chiefly in taking aneroids outdoors on a very cold winter night and later heating in a receiver surrounded by hot water, with the conclusion that in good instruments thermal errors are negligible compared with other errors, and therefore need not be seriously considered until more is done to eliminate mechanical and elastic errors.

In the free atmosphere tests 25,000 observations were taken in order to keep track of the history of each aneroid in the interim between successive air-pump tests, to ascertain to what extent it is fair to pass judgment on an aneroid from observations on the fluctuations of its correction from day to day, and to detect secular changes.

The air-pump tests were, however, the most important, and also the most laborious, as it was necessary to hold the aneroids for 24 hours at the lowest pressure in order to observe the creeping effect due to imperfect elasticity. This determination of the creep appears to be the crucial point in ascertaining the quality of an aneroid.

As a sequel to the foregoing investigation the development of standard specifications for the purchase of aneroids has been undertaken at the joint request of other branches of the Government service and of manufacturers. The final results of the Bureau's work in this field cannot fail to be of great value in improving the design, manufacture, and use of these important instruments.

PHYSICAL TESTING OF COTTON YARN.

W. S. LEWIS, of the Bureau of Standards, completed, in June, 1912, a series of studies and investigations on the effects of various factors, including humidity upon cotton yarns, for the purpose of improving the technical regulations of the trade and developing cotton yarn specifications, as well as to improve methods of testing.

The work consisted of a general consideration of single- and two-ply yarns as to variations in size, twist, and tensile strength of yarns within cops, bobbins, skeins, respectively, etc., and also their behavior under various relative atmospheric humidities.

SUMMARY.

The results of greatest interest ascertained through this investigation and now prepared for publication are as follows:

1. In this series of tests it appears that "two-ply" yarns were nearer the "spinners" number than the "singles" yarns.

2. That "singles" yarns are produced with greater uniformity in size than "two-ply" yarns.

3. It is not more difficult to spin coarse yarns to the required size than fine yarns.

4. Under usual atmospheric changes the size of a 36/1 yarn may vary as much as 2 counts, and an 80/1 yarn over 4 counts, or, in other words, 5.5 per cent. in each case. The "two-ply" yarns are not as susceptible to changes due to humidity in the atmosphere, although they vary from ½ a count

on 10/2 yarn to almost 5 counts on 96/2 yarn, with an average of 4.5 per cent. on all sizes.

5. Under the conditions outlined in No. 4, the yardage in "singles" yarns can be increased or decreased from 1700 to 3700 yards per pound, or 5.5 per cent., according to size of the yarn. The "two-ply" yarns can be changed in yardage by the humidity of the atmosphere, the difference in length ranging between 250 and 2000 yards per pound, or about 4.5 per cent.

6. The irregularity in spinning of the twist in the "singles" yarns is very apparent, but the folding or twisting of two yarns in a "two-ply" yarn can be accomplished with greater uniformity.

7. The tensile strength of yarn depends upon the kind of fibre, length of staple, and its treatment in manufacture. The results of the "lea" method compared with the single-strand method of determining the tensile strength, fully outlined, indicate the superiority of the single-strand method.

8. The tensile strength of cotton yarns increases with an increase of moisture up to 85 per cent. relative humidity (the highest point reached in this investigation). The "singles" yarns are influenced more than the "two-ply" yarns. Calculating from 55 per cent. to 85 per cent. relative humidities, the "singles" increase 17 per cent. and the "two-ply" yarns increase 11 per cent. in tensile strength. Further tests were made with the "two-ply" yarns, and the results show that the strength can be increased more than 16 per cent. between a relative atmospheric humidity of 85 per cent. and a relative atmospheric humidity of 45 per cent.

9. The quantity of sizing in the various makes of "singles" yarns varied from 0.5 per cent. to 1.5 per cent., while the "two-ply" yarns ranged from 1.5 per cent. to 2.5 per cent.

10. The yarn-counts can be determined upon small specimens with an accuracy much greater than it can be manufactured. A 30-yard length is sufficient in determining the size of a yarn, as it was found that the yarn count variation within the cop or bobbin itself is usually much greater than differences found between 120-yard and 30-yard lengths.

THE TESTING AND PROPERTIES OF TEXTILE MATERIALS.

THE Bureau is sending to press a circular which will be of great interest to the textile industry. The textile industry is one of the largest of the manufacturing activities of the United States. The products find their way into both the domestic and foreign markets and form the basis for commercial transactions involving a very large amount of money and affecting every individual consumer. It therefore becomes desirable to have methods of testing which may be applied easily and which will furnish a reliable means for reaching a harmonious agreement between producer, distributer, and consumer. The accurate description of the material and quality, supplemented by an indication of the conditions and methods of test by which it is to be determined, forms a specification upon which it should be possible for the buyer and seller to reach an agreement. For textile materials little standardization has been undertaken, and the industry is dependent very largely upon the units and methods of measurement as carried out by certain manufacturers and individuals.

The study of the physical and chemical properties of textile material by means of laboratory tests has been carried on in this country in a more or less desultory fashion for a great many years. Quite recently, however, the development of more systematic and greatly-improved methods of testing, with a consequent augmented accumulation of data, has given the results obtained a much more practical significance than in former years.

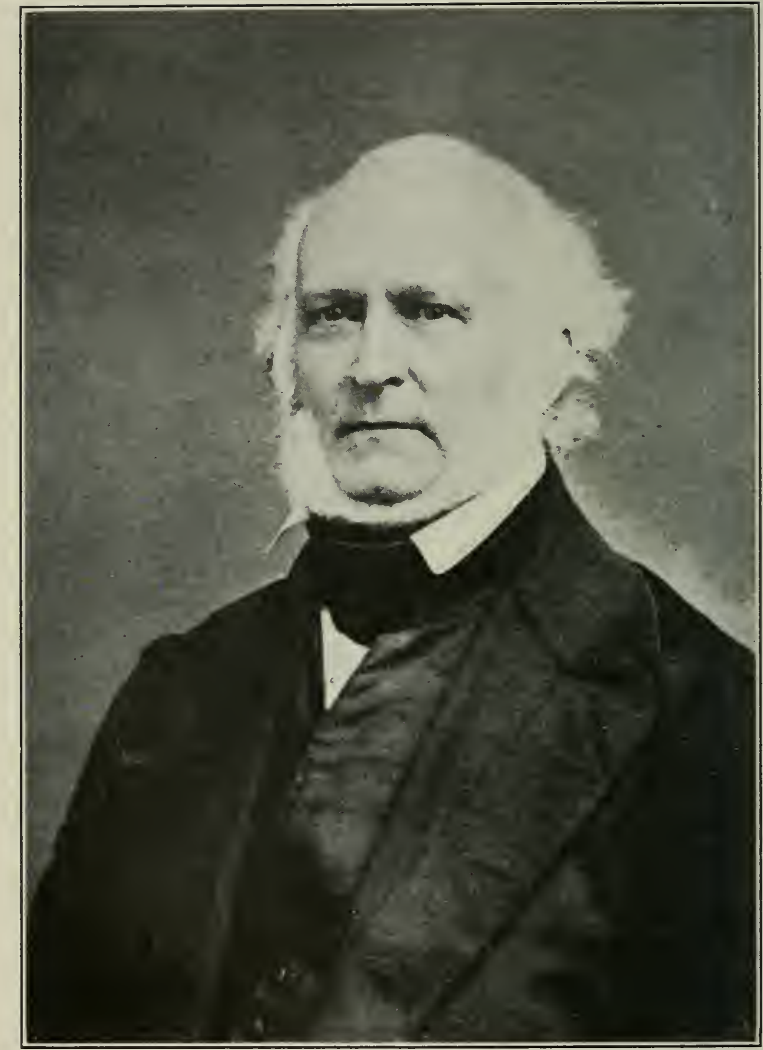
In England, France, Germany, Austria, Italy, and Japan advanced methods of testing have been utilized with remarkable results. The present general interest in the necessity for better methods and standardization of tests has resulted in the establishment of testing apparatus in textile institutions, public testing laboratories, stores, and mills. A large number of samples are submitted to the Bureau of Standards for investigation not only from the Government departments but by manufacturers and dealers. The fact that this work is rapidly increasing is good evidence of the value of the information received. The Bureau will gladly co-operate with institutions, investigators, manufacturers, and consumers, not only in the execution of scientific testing and standardization but also in furnishing information in its possession concerning methods of testing and the interpretation of results. It will be pleased, also, to help in the design and construction of special apparatus. The scope of testing which the Bureau is now prepared to undertake is summarized below.

1. *Determinations upon Raw and Unspun Fibres:*
    - (*a*) Indentity of fibre.
    - (*b*) Approximate length.
    - (*c*) Moisture content and "regain."
    - (*d*) Quantity of oil, grease, and foreign substances contained.
    - (*e*) Percentage loss in scouring raw wool.

2. *Determinations upon Yarn, Thread, and Twine:*
    - (*a*) Length.
    - (*b*) Tensile strength and elasticity.
    - (*c*) Count or number.
    - (*d*) Twist.
    - (*e*) Percentage of loading, sizing, and coloring material.
    - (*f*) Percentage fibre composition.

3. *Determinations upon Fabric:*
    - (*a*) Weight.
    - (*b*) Tensile strength and elongation.
    - (*c*) Percentage fibre composition.
    - (*d*) Thread count.
    - (*e*) Yarn number or size.
    - (*f*) Folding endurance.
    - (*g*) Action of light on colors.

Electric-Light Carbons from Tar. ANON. (*Sci. Amer.*, cvii, No. 23, 477.)—High-grade carbons can now be obtained from tar, by a process invented in Sweden. The method depends on the fact that finely-divided carbon forms a large percentage of tar, as the black color is due to carbon particles suspended in an otherwise dense and transparent yellowish-brown liquid. By this process the carbon can be separated from the liquid, and can then be moulded into any desired shape. The powdered carbon can be pressed to form electric-light carbons or into larger sizes for electrodes.



JAMES H. CRESSON.

In memory of whom was recently established, by a friend of the Institute, the "James H. Cresson Memorial Fund" of $50,000. Mr. Cresson was born December 26, 1793, and died February 3, 1880. He was a member of the Institute from 1836 to the time of his death.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, February 19, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 19, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 21.

The standing committees for the year 1913–14 were announced.

Following the meeting of the Institute for the transaction of this business, a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers.

President Clark introduced the speaker of the evening, Prof. Elihu Thomson, of Swampscott, Massachusetts, who presented a paper on the "Transmission of Electrical Energy."

The speaker reviewed the progress made in the electrical transmission of power for lighting and other industrial purposes, telephony, telegraphy, including wireless telegraphy, during the past thirty years and accompanied his remarks by numerous experimental illustrations of a novel and striking kind. He referred to the fact that the parallel coupling of alternating current transformers was first done in the Hall of the Institute in 1879 and exhibited replicas of these transformers in operation. A simple and elegant explanation was given of the fact that electromagnetic waves used in wireless telegraphy follow the earth's curvature. In referring to the possibilities of transmission by direct currents of high voltage the speaker exhibited a new form of static machine, the revolving parts of which consisted of aluminum wings stoutly attached to insulated hubs, the glass portion being stationary. This machine operates on the Wimshurst principle, but has the advantage of being a thoroughly mechanical piece of apparatus.

After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1913,

Of the Board of Managers.

INSTRUCTION.	ELECTIONS AND RESIGNATIONS.
Lawrence T. Paul, *Chairman*,	W. C. L. Eglin, *Chairman*,
Charles Day,	John J. Gibson,
George A. Hoadley,	Robert W. Lesley,
E. V. McCaffrey,	Robert S. Perry,
James S. Rogers.	Alexander P. Robinson.

STOCKS AND FINANCE.

Walton Forstall, *Chairman,*
Cyrus Borgner,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

EXHIBITIONS.

John Birkinbine, *Chairman,*
Francis T. Chambers,
James M. Dodge,
W. C. L. Eglin,
C. A. Hexamer.

ENDOWMENT.

Henry Howson, *Chairman,*
James M. Dodge,
Alfred C. Harrison,
Richard Waln Meirs,
Coleman Sellers, Jr.

PUBLICATIONS.

Louis E. Levy, *Chairman,*
John Birkinbine,
W. C. L. Eglin,
George A. Hoadley,
E. H. Sanborn.

SECTIONAL ARRANGEMENTS.

Charles Day, *Chairman,*
Francis T. Chambers,
W. C. L. Eglin,
Louis E. Levy,
Lawrence T. Paul.

EXECUTIVE.

E. H. Sanborn, *Chairman,*
James M. Dodge,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs.

Of the Institute.

LIBRARY.

N. W. Akimoff,
E. V. d'Invilliers,
Richard Gilpin,
Clarence A. Hall,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
George F. Stradling,
John C. Trautwine, Jr.

MEETINGS.

G. S. Barrows,
G. H. Clamer,
George R. Henderson,
H. A. Hornor,
Herbert E. Ives,
M. M. Price,
James S. Rogers,
Geo. D. Rosengarten,
Coleman Sellers, Jr.,
C. C. Tutwiler.

MUSEUMS.

Henry F. Colvin,
Charles Day,
James M. Dodge,
Richard Gilpin,
George A. Hoadley,
H. F. Keller,
Wilfred Lewis,
A. E. Outerbridge, Jr.,
Wm. H. Thorne,
Wm. J. Williams.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, February 5, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 5, 1913.

Mr. J. A. P. Crisfield was elected Chairman for the year 1913, and occupied the chair.

The following report was presented for first reading:

No. 2523.—Ellis Adding Typewriter.

The following were accepted for examination:

No. 2524.—The Applications of the Gyroscope to Marine Purposes. Elmer A. Sperry.
No. 2526.—C. Francis Jenkins' Motion Picture Apparatus.
No. 2527.—Norton Alundum Refractories.
No. 2528.—Non-Toxic Bactericide "Pyxol."
No. 2529.—The Work of Albert Sauveur in Connection with the Metallography of Iron and Steel.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Thursday evening, January 30, 1913, at 8 o'clock.

Dr. George A. Hoadley occupied the chair.

The Chairman introduced Dr. Edward P. Hyde, Director of the Physical Laboratory, National Electric Lamp Association, Cleveland, Ohio, who read an interesting paper on "The Physical Laboratory of the National Electric Lamp Association—A *Résumé* of the Activities of the Laboratory in the Development of the Modern Science of Illumination."

After an introduction reviewing the organization of the illuminating engineers of this country and abroad and the development of the profession by the application of the work of physicists, physiologists, and psychologists, Dr. Hyde described the building and equipment of the present laboratory of the National Electric Lamp Association and the work done there during the past four years.

With the aid of lantern slides he described the new laboratory now nearing completion in the suburbs of Cleveland. The thanks of the meeting were extended by Dr. Hyde.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the section was held on Thursday evening, February 13, 1913, at 8 o'clock, in the Hall of the Institute.

The meeting was called to order by the president of the section, Professor A. E. Outerbridge, Jr.

With a few apt remarks on the extraordinarily rapid growth of the science of Metallography and on the already extensive practical application of its principles in the field of iron and steel manufacture, the Chairman introduced Mr. Albert Sauveur, B.S., Professor of Metallurgy and Metallography, Harvard University, who delivered an illustrated lecture entitled "An Outline of the Metallography of Iron and Steel."

Professor Sauveur showed an interesting series of photo-micrographs, depicting the proximate composition of pure iron, cast and wrought iron, cast steel, etc. With the aid of these pictures he defined the terms used in metallography. He then showed curves and explained critical temperature, annealing, tempering, etc.

His remarks illustrated clearly what had been done in the field of metallography during the past twenty years, since the science had begun its present era of development and application.

After a brief discussion, the thanks of the meeting were extended Professor Sauveur.

Adjourned.

William E. Bullock,
Acting Secretary.

CAMP LIFE IN PHILADELPHIA.

Mr. W. N. Jennings, member, delivered a lecture bearing the above title on Thursday evening, February 6, 1913, in the Hall of the Institute.

With the aid of numerous lantern slides made from his own photographs Mr. Jennings described how for four months in the year his family reaps the benefit of sunlight and fresh air at his camp situated on picturesque ground within the city limits.

The lecture was well attended, and the audience showed marked appreciation of Mr. Jennings's very interesting pictures.

ON THE EDGE OF ALASKA.

A lecture bearing the above title and illustrated by 150 beautifully-colored lantern photographs was delivered by Dr. George Flowers Stradling, member, on Friday evening, January 31, 1913, in the Hall of the Institute.

Many of the pictures shown were taken by Dr. Stradling when on a visit to this remarkable country last summer, the remainder being loaned by Mr. Clark, for two years a resident in Alaska.

The reproduction of the color effects in some of the glacier and sunset scenes shown was remarkably true to nature, and the audience was well able to obtain a very representative idea of the features of this interesting country.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated meeting of the Board of Managers, February 13, 1913.)

RESIDENT.

Mr. Henry I. Brown, 435 Walnut Street, Philadelphia, Pa.
Mr. Wm. D. Disston, Disston Saw Works, Tacony, Philadelphia, Pa.
Mr. C. H. Geist, Land Title Building, Philadelphia, Pa.
Mr. Edwin M. Goldsmith, Friedberger-Aaron Mfg. Co., Logan Station, Philadelphia, Pa.
Mr. John L. Hand, 222 Walnut Street, Philadelphia, Pa.
Dr. Joseph Head, 1500 Locust Street, Philadelphia, Pa.
Miss Emily E. Howson, 109 North Thirty-fourth Street, Philadelphia, Pa.
Mr. J. C. Johnson, Superintendent Telegraph, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.
Mr. Lionel Faraday Levy, 1424 North Fifteenth Street, Philadelphia, Pa.
Dr. Paul A. Lewis, Director of Laboratory, The Henry Phipps Institute, University of Pennsylvania, Philadelphia, Pa.
Hon. James P. McNichol, 222 North Nineteenth Street, Philadelphia, Pa.
Mr. W. H. Marshall, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pa.
Mr. J. Walter Miles, Irwin, Pa.
Mr. Clement D. Rinald, 1142 North Hancock Street, Philadelphia, Pa.
Mr. Edward Rittenhouse, Linwood, Delaware County, Pennsylvania.
Mr. William C. Wetherill, 307 West Springfield Avenue, St. Martin's, Philadelphia, Pa.

NON-RESIDENT.

Mr. Edwin Duryea, Jr., 1314 Humboldt Bank Building, San Francisco, Cal.
Lieut. R. E. Gillmore, Sperry Gyroscope Company, 74 Broadway, New York, N. Y.
Mr. A. DW. Smith, Coal Exchange Building, Wilkes-Barre, Pa.
Mr. Leon E. Thomas, Birdsboro Steel Foundry and Machine Company, Birdsboro, Pa.
Mr. Christopher Wren, Plymouth, Pa.

Changes of Address.

Dugald Clerk, F. R. S., 58, Lincoln's Inn Fields, London, W. C., England.
Mr. Walter Cox, Pennsylvania Wire Glass Company, Pennsylvania Building, Philadelphia, Pa.
Mr. Edward V. D'Invilliers, 506 Walnut Street, Philadelphia, Pa.
Mr. Walter H. Fulweiler, 1706 North Broad Street, Philadelphia, Pa.
Mr. Radclyffe Furness, Midvale Steel Company, Philadelphia, Pa.
Mr. B. Spencer Greenfield, 4420 Fleming Street, Roxborough, Philadelphia, Pa.

MR. ARTHUR C. JACKSON, 6445 Greene Street, Germantown, Philadelphia, Pa.
MR. J. P. JEFFERSON, Warren, Pa.
MR. MALCOLM R. MACLEAN, American Steel Foundries, Pittsburgh, Pa.
MR. JOHN WIEGAND, 1931 North Seventh Street, Philadelphia, Pa.
DR. FRANCIS WYATT, 402 West Twenty-third Street, New York City.

NECROLOGY.

Mr. John Fritz, 155 Market Street, Bethlehem, Pa.

LIBRARY NOTES.

Purchases.

American Public Health Association.—Standard Methods for the Examination of Water and Sewage. 1912.
CAHEN, E., and W. O. WOOTON.—The Mineralogy of the Rarer Metals. 1912.
COLE, W. H.—Light Railways at Home and Abroad. 1899.
Engineering and Mining Journal.—Handbook of Mining Details. 1912.
Engineering Index Annual, 1911.
FIDLER, T. C.—Calculations in Hydraulic Engineering. 1902.
GRAY, A., and G. B. MATHEWS.—A Treatise on Bessel Functions. 1895.
HAVARD, F. T.—Refractories and Furnaces. 1912.
HINE, C. D.—Modern Organization. 1912.
HUGHES, H. J., and A. T. SAFFORD.—A Treatise on Hydraulics. 1912.
HUMPHREYS, A. C.—Lecture Notes on Some of the Business Features of Engineering Practice. 1912.
International Catalogue of Scientific Literature.—B, 10th annual issue, 1912; C, 10th annual issue, 1912; H, 10th annual issue, 1912; J, 10th annual issue, 1912.
Jahrbuch für Photographie, 1912.
LEHFELDT, R. A.—Electro-chemistry, pt. 1. 1908.
LOVE, A. E. H.—A Treatise on the Mathematical Theory of Elasticity. 1906.
LOW, D. A.—Practical Geometry and Graphics. 1912.
LUNGE, G.—The Manufacture of Sulphuric Acid and Alkali, vol. 2, pts. 1 and 2. 1909.
MARSH, H. W.—Industrial Mathematics. 1913.
NOELTING, E., and A. LEHNE.—Aniline Black. 1909.
PAGE, V. W.—The Modern Gasoline Automobile. 1912.
Photograms of the Year 1912.
Physical Society of London.—The Scientific Papers of Sir Charles Wheatstone. 1879.
RUTHERFORD, E.—Radioactive Substances. 1913.
THORPE, E.—A Dictionary of Applied Chemistry. 1912.
United States Catalog Books in Print January 1, 1912. 1912.

Gifts.

Rhode Island Public Utilities Commission, Annual Reports for the years 1865, 1868, 1874, 1880, 1883, 1885–1892 inc., 1894–1899 inc., 1901–1904 inc., 1911. Providence, no date. (From the Commission.)

New Hampshire Railroad Commission, Annual Reports for the years 1890–1898 inc., 1901–1905 inc., and 1911. Report of the Public Service Commission. Concord, no date. (From the State Library.)

Montana Board of Railroad Commissioners,—4th and 5th Annual Reports. Helena, no date. (From the Board.)

Nebraska State Railway Commission,—4th Annual Report. Lincoln, 1911. (From the Commission.)

Institution of Civil Engineers, Minutes and Proceedings, Volume 190. London, 1911. (From the Institution.)

Drexel Institute, Year Book, 1912–1913. Philadelphia, 1913. (From the Institute.)

Wisconsin Historical Society, Service with the Third Wisconsin Infantry. By Julian W. Hinkey. Madison, 1912. (From the Society.)

Wisconsin Historical Society, Messages and Proclamations of Wisconsin War Governors. Madison, 1912. (From the Society.)

Iowa Geological Survey,—Annual Report for 1910–11, volume 21. Des Moines, 1912. (From the Survey.)

Ohio Geological Survey,—Peat Deposits, Bulletin 16. Columbus, 1912. (From the Survey.)

National Electric Light Association,—Proceedings 35th Convention, volumes 1–4. New York City, 1912. (From the Association.)

Vermont Public Documents 1911–12; Commissioner of Agriculture, 4th Annual Report, 1912; Public Service Commission, 13th Biennial Report, 1911–12; State Highway Commissioner, 7th Biennial Report, 1911–12; Legislative Directory, 1912; Bank Commissioner, Report 1911; Board of Library Commissioners, 9th Biennial Report, 1911–12. Montpelier, 1911–12. (From the State Library.)

University of Cincinnati, Annual Catalogue 1912–13. Cincinnati, no date. (From the University.)

Wisconsin Historical Society, Catalogue of Newspaper Files 1911. Madison, 1911. (From the Society.)

Smithsonian Institution, Annual Report 1911. Washington, 1912. (From the Institution.)

PUBLICATIONS RECEIVED.

United States Geological Survey, George Otis Smith, Director. Mineral Resources of the United States, calendar year 1911. Part i, metals; part ii, non-metals. Two volumes, maps, 8vo. Washington, Government Printing Office, 1912.

Canada Department of Mines, Mines Branch: The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada during the calendar year 1911, by Cosmo T. Cartwright, B.Sc., Assistant Mining Engineer, Division of Mineral Resources and Statistics. 85 pages, 8vo. Ottawa, Government Printing Bureau, 1913.

Ontario Bureau of Mines, Twenty-first annual report, 1912, being volume 21, part 1. 309 pages, illustrations, maps, 8vo. Toronto, Printer to the King, 1912.

Iowa State College of Agriculture and Mechanic Arts, Bulletin No. 29, Engineering Experiment Station: Costs of Producing Power in Iowa with Iowa Coals, by H. W. Wagner. 36 pages, diagrams, 8vo. Ames, Iowa.

A Practical Device to Simulate the Working of Nervous Discharges, by S. Bent Russell, St. Louis, Mo. Reprinted from the *Journal of Animal Behavior,* January–February, 1913, vol. 3, No. 1, pp. 15–35. 35 pages, illustrations, 8vo.

U. S. Bureau of Mines, Miners' Circular 10, Mine Fires and How to Fight Them, by James W. Paul. 14 pages, 8vo. Washington, Government Printing Office, 1912.

The Obligations of the United States as to Panama Canal Tolls. Speech of Hon. Elihu Root, of New York, in the Senate of the United States, January 21, 1913. 31 pages, 8vo. Washington, 1913.

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OF

THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXV APRIL, 1913 No. 4

THE RAILWAY TUNNELS OF NEW YORK CITY.[1]

ALFRED NOBLE, C.E., L.L.D.,

Consulting Engineer, New York City.

WHEN I accepted the invitation to address the Institute on the subject of the "Railway Tunnels of New York City," the full scope which might be contemplated did not occur to me. My first thought was rather of the high honor recently conferred on me by the Institute which made its invitation a command to be obeyed unhesitatingly.

By the term "tunnel" we usually refer to an underground passage formed by excavating a heading and enlarging this to the full section required; but a tunnel can be formed in other ways, as, for example, the tunnel under Detroit River, formed of sections built in part at a distance, towed to the site, sunk in a prepared trench, and then completed with floating plant and working force. The term may therefore be considered as referring to the completed structure rather than to the method for constructing it; and the view may be held that the subject assigned to me refers not merely to tunnels under the waterways around

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[1] Presented at the stated meeting of the Institute held Wednesday, November 20, 1912.

[Dr. Noble received the Institute's Elliott Cresson Medal May 15, 1912, in recognition of his distinguished achievements in the field of civil engineering.—ED.]

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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Manhattan Island, but to all the sub-surface structures used for railway purposes within the limits of the city. Accepting this view for our present purpose, it is proposed to give in this paper a brief outline of the several railway tunnel and subway systems in New York City and to follow this with more particular reference to the construction of tunnels under the rivers enclosing the island of Manhattan.

To avoid confusion in referring to the several districts of Greater New York, the one formerly embraced within the older city of New York will be referred to as the island or borough of Manhattan, or simply as Manhattan; the former city of Brooklyn as the borough of Brooklyn, or Brooklyn; the northwesterly portion of Long Island, lying along East River north of Newtown Creek and extending eastward some distance along Long Island Sound, as the borough of Queens, or Queens, and the portion of Westchester County lying east of Harlem River and extending eastward for some distance along Long Island Sound, as the borough of The Bronx, or The Bronx.

OUTLINES OF EXISTING TUNNEL SYSTEMS.

New York Central & Hudson River Railroad Tunnel.

This is located under Park Avenue in New York City, and was built in 1872–5. It is the oldest railroad tunnel now in use in the city. It contains four tracks and extends from Fifty-sixth Street to Ninety-sixth Street, a total distance of two miles. A short section, 550 feet long, was built by ordinary tunnelling methods, the remainder in open cutting. It was a notable work when built.

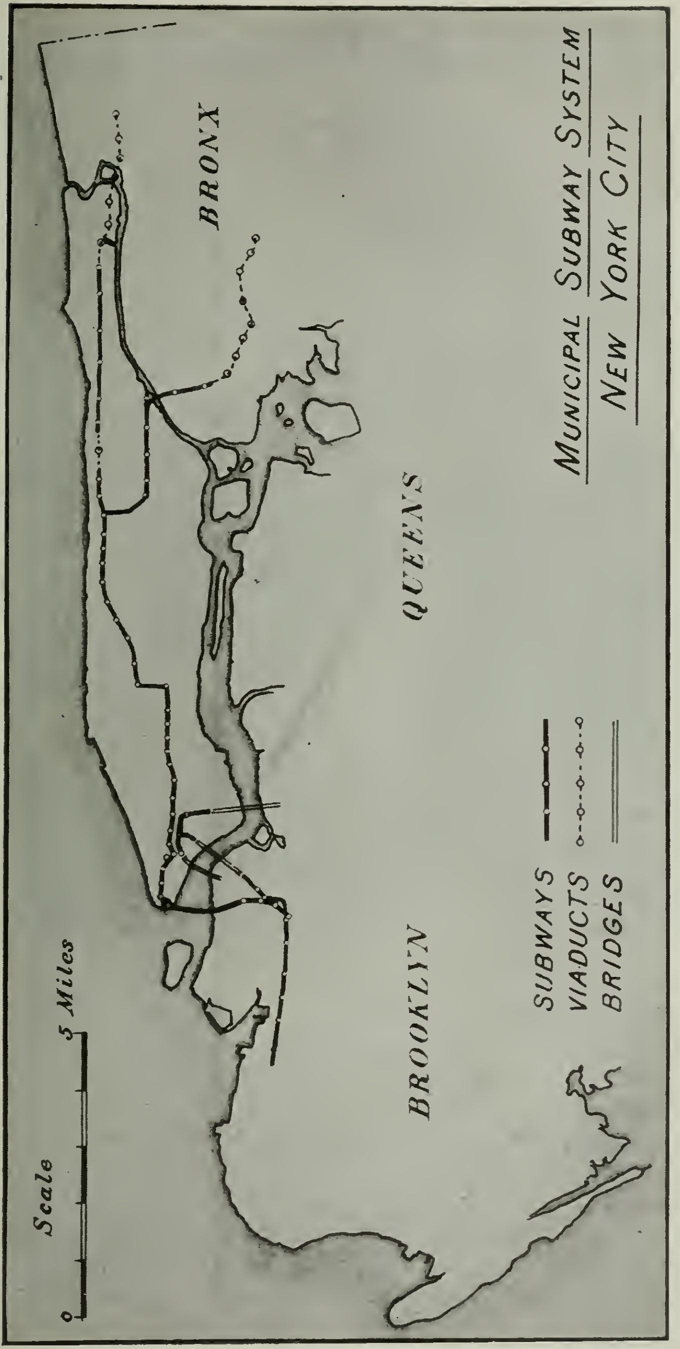
Long Island Railroad Tunnel in Brooklyn.

The so-called Atlantic Avenue Improvement of the Long Island Railroad, consisting in part of tunnel built in open-cutting and partly of elevated railroad, was carried out in 1904–8. The tunnel structure is about 2¼ miles long and provides for two tracks.

New York City Subway Tunnels.

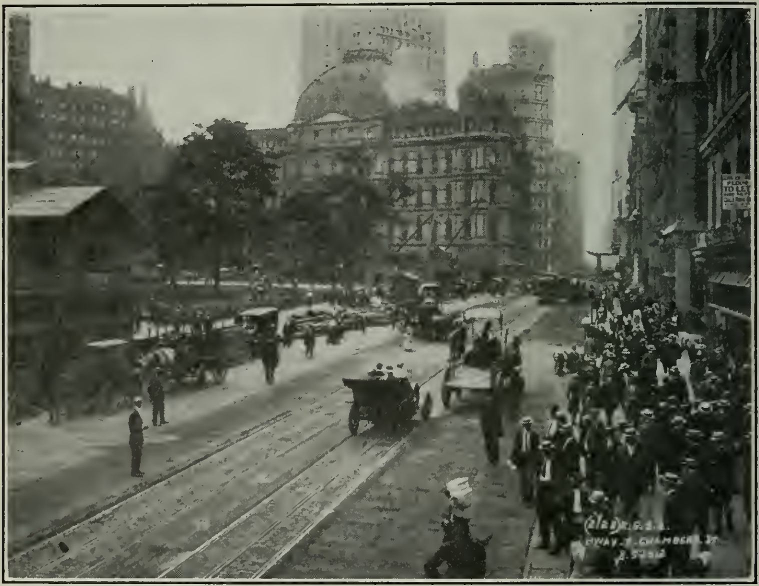
The rapid transit subway system now in use, or nearly ready for use, is indicated in Plate 1. The portions in Manhattan and Brooklyn consist almost entirely of tunnels, the total length of

PLATE I.

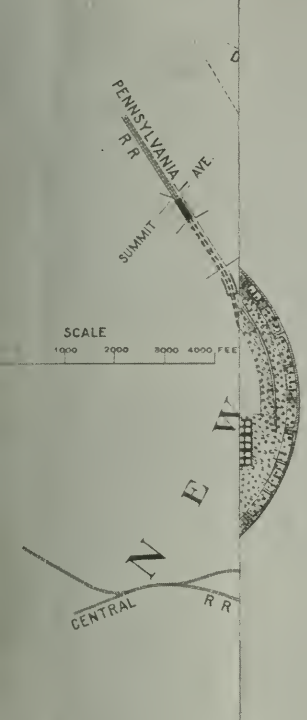

MUNICIPAL SUBWAY SYSTEM
NEW YORK CITY
BRONX
QUEENS
BROOKLYN
SUBWAYS
VIADUCTS
BRIDGES
Scale
0
5 Miles

tunnel structures being 24.7 miles; of this length about 5.1 miles have been built by tunnelling methods, the remainder in trenches excavated from the surface of the ground, usually called open-cut. The interference with business along the streets was serious, and gave rise to much criticism of the method. These trenches were of sufficient width to accommodate two or more tracks, a large proportion containing four. In the Brooklyn and Center Street sections recently built these multiple track structures are generally subdivided by longitudinal partitions forming two to eight single-track tunnels side by side in one excavation. The total track mileage of tunnels is 78 miles. In recent work in Manhattan the so-called open-cutting has really consisted of excavation and construction under cover, the only open-cutting consisting of the removal of the pavement and sufficient underlying earth to permit laying a planked roadway under which the work is continued. The open-cutting is done at night, so that the interference with street traffic is negligible. (Plate 2.) Openings along the sidewalk or in cross streets at intervals of a few

PLATE 2.



New York City Subway. Excavation under cover.


PENNSYLVANIA AVE.
R R
SUMMIT
SCALE
1000 2000 3000 4000 FEE
N E W
CENTRAL R R

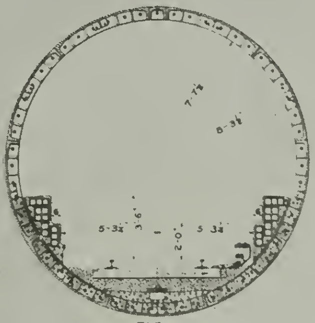
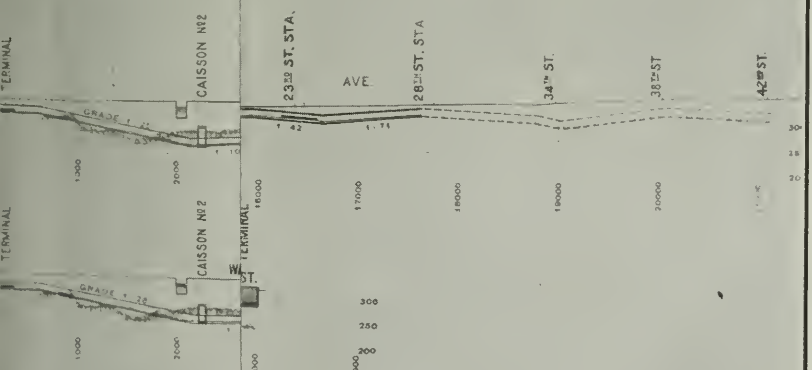
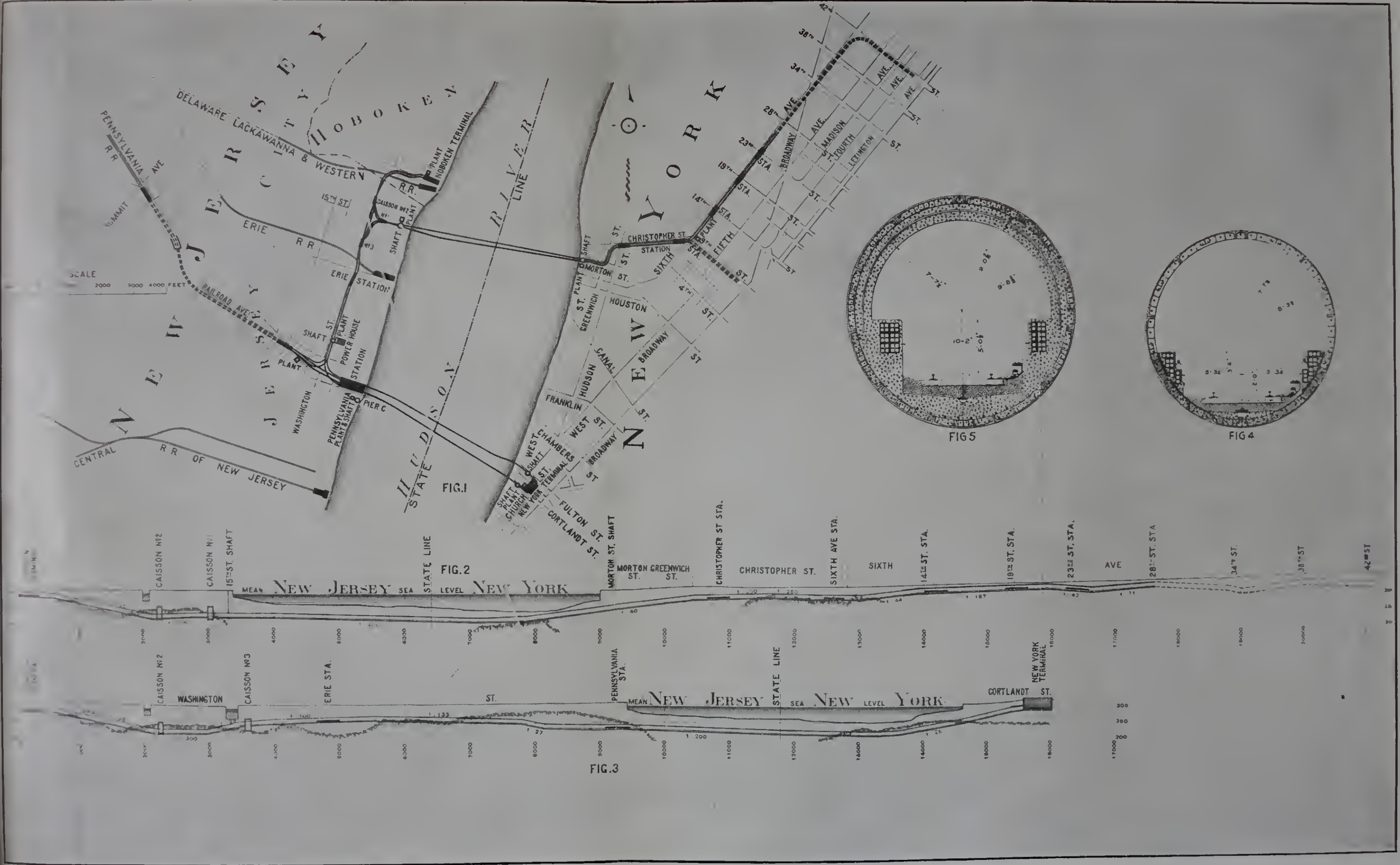

7-7½
8-3½
3-6
5-3½
2-0
5-3½

FIG 4


TERMINAL
CAISSON No2
23RD ST. STA.
AVE.
28TH ST. STA
34TH ST.
38TH ST
42ND ST.
GRADE
1.42
1.74
1000
2000
16000
17000
18000
19000
20000
300
250
200
TERMINAL
CAISSON No2
TERMINAL
W ST.
GRADE
300
250
200
1000
2000
16000
17000



Hudson & Manhattan Railroad System.

blocks are provided through which excavated materials are hoisted and materials for constructing the tunnels are lowered. The work is much more costly than if carried on in the open. Present convenience of the public is secured at the expense of greater capital cost and greater fixed charges, which the public must carry for a long, indefinite period.

It will be noted by reference to the map of existing subway lines (Plate 1) that there are river crossings at three localities, two of which, one from the lower end of Manhattan Island to Brooklyn under the East River, the other between the island and the borough of The Bronx near 145th Street, are by means of tunnels; while the third, from the upper end of Manhattan Island to the mainland, is by means of a three-track bridge.

Hudson & Manhattan Railroad System.

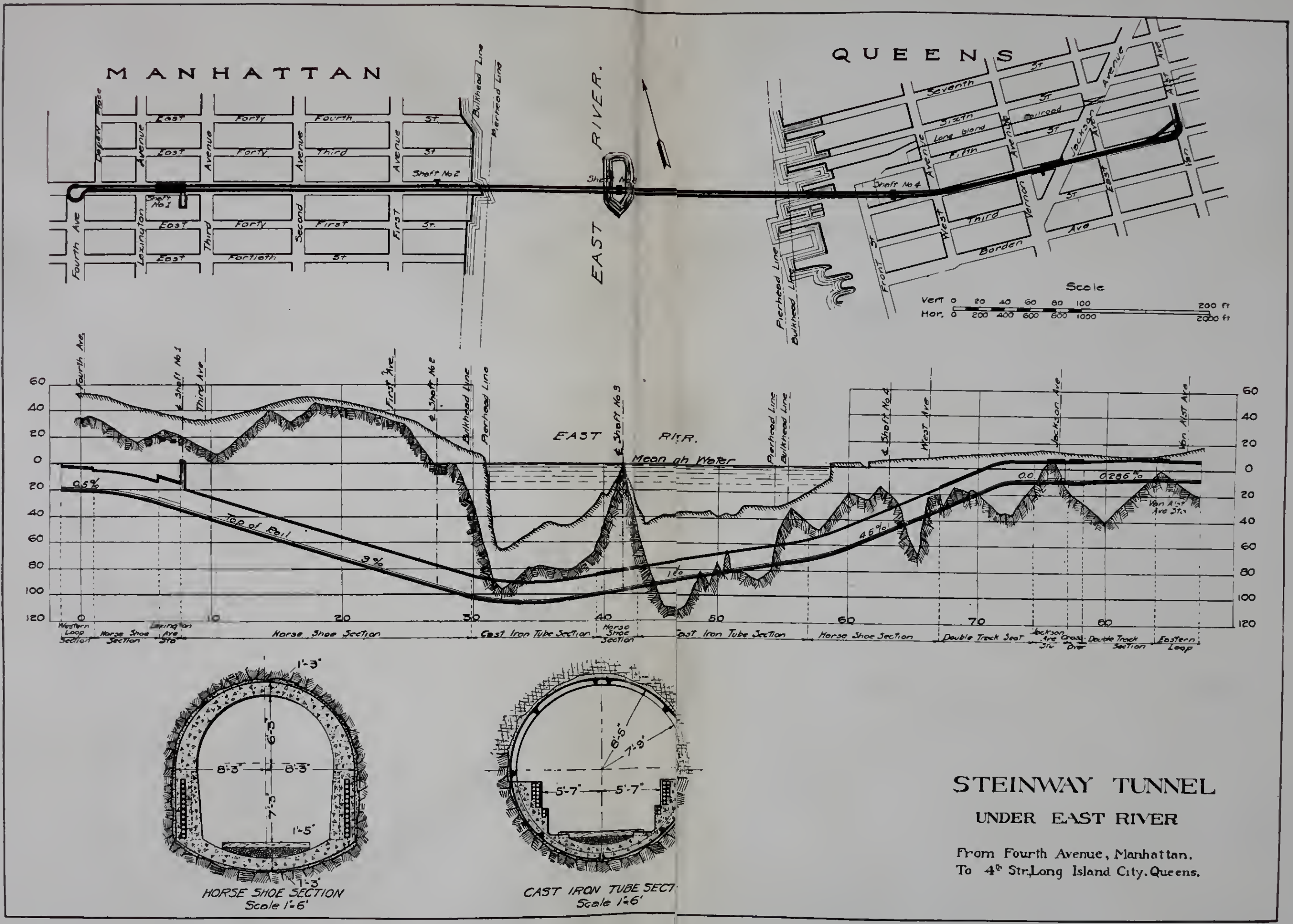
The tunnel system of the Hudson & Manhattan Railroad Company—commonly called the McAdoo tunnels in honor of the public-spirited man who pushed the project to completion—is shown in Plate 3. It embraces four tunnels under North River, with various extensions on both sides. The so-called uptown tunnels, two in number, pass eastward from Jersey City from a point near Fifteenth Street, about midway between the terminals of the Erie and the Delaware, Lackawanna & Western Railroads, and reach the Manhattan side at the foot of Morton Street, passing under Morton, Greenwich, and Christopher Streets and Sixth Avenue to the present terminal at Thirty-third Street. The two downtown tunnels start from the Manhattan terminal at Church Street, between Fulton and Cortlandt Streets, one tunnel passing under Fulton Street to the river, the other under Cortlandt Street; at the Church Street terminal they are connected by loops where the passenger platforms are placed; continuing westward under the river they pass under the Jersey City station of the Pennsylvania Railroad, with connections for passengers by means of elevators, and emerge into open air about 6800 feet farther westward. The uptown and downtown tunnels are connected on the New Jersey side by two tunnels running parallel with the river and extended northwards to the Delaware, Lackawanna & Western terminal. By means of these several connections passengers are carried quickly and directly from either Manhattan terminal of the McAdoo tunnels to any of the three railroad terminals—the Pennsylvania, Erie, or Delaaware, Lackawanna & Western—or by a somewhat circuitous route with two under-river crossings, from one Manhattan terminal to the other—that is, from Sixth Avenue and Thirty-third Street to Church and Cortlandt Streets. Profiles of the system are shown in Plate 3.

In the construction of this system a novel feature was introduced by sinking reinforced concrete caissons containing short sections of tunnels at several of the junction points.

In the McAdoo system there are about 7.6 miles of shield-driven tunnels. In addition to this mileage, a structure containing, by longitudinal subdivision, two single-track tunnels has been built in open-cutting under Sixth Avenue from Twelfth to Thirty-third Street, making a total of 9.6 miles of single-track tunnel now in operation.

Steinway or Belmont Tunnels.

Both the city subways and the McAdoo tunnels were designed for rolling stock of somewhat smaller dimensions than the standard railroad car. These systems provided means for quick transit between Manhattan Island and New Jersey and between Manhattan and the neighboring boroughs of Brooklyn and The Bronx, but left the rapidly-developing borough of Queens unprovided for. To meet this deficiency, Mr. August Belmont and his associates undertook, in 1905, the construction of two single-track tunnels for street car traffic from Park Avenue, Manhattan, eastward under Forty-second Street to East River, thence under the river to Long Island City, reaching the surface about 3000 feet inland. (See Plate 4 for map and profile.) This was undertaken under an old franchise granted in 1891 to Dr. Steinway. Unfortunately, unforeseen difficulties in their construction made it impossible to complete the tunnels within the term of the franchise, which expired January 1, 1907. They were completed in the summer of that year, but they have not been put in use because of dispute between the owners and the city, although urgently needed by the public. It is understood that an agreement has been reached under which these tunnels may be used.



HORSE SHOE SECTION
Scale 1"=6'

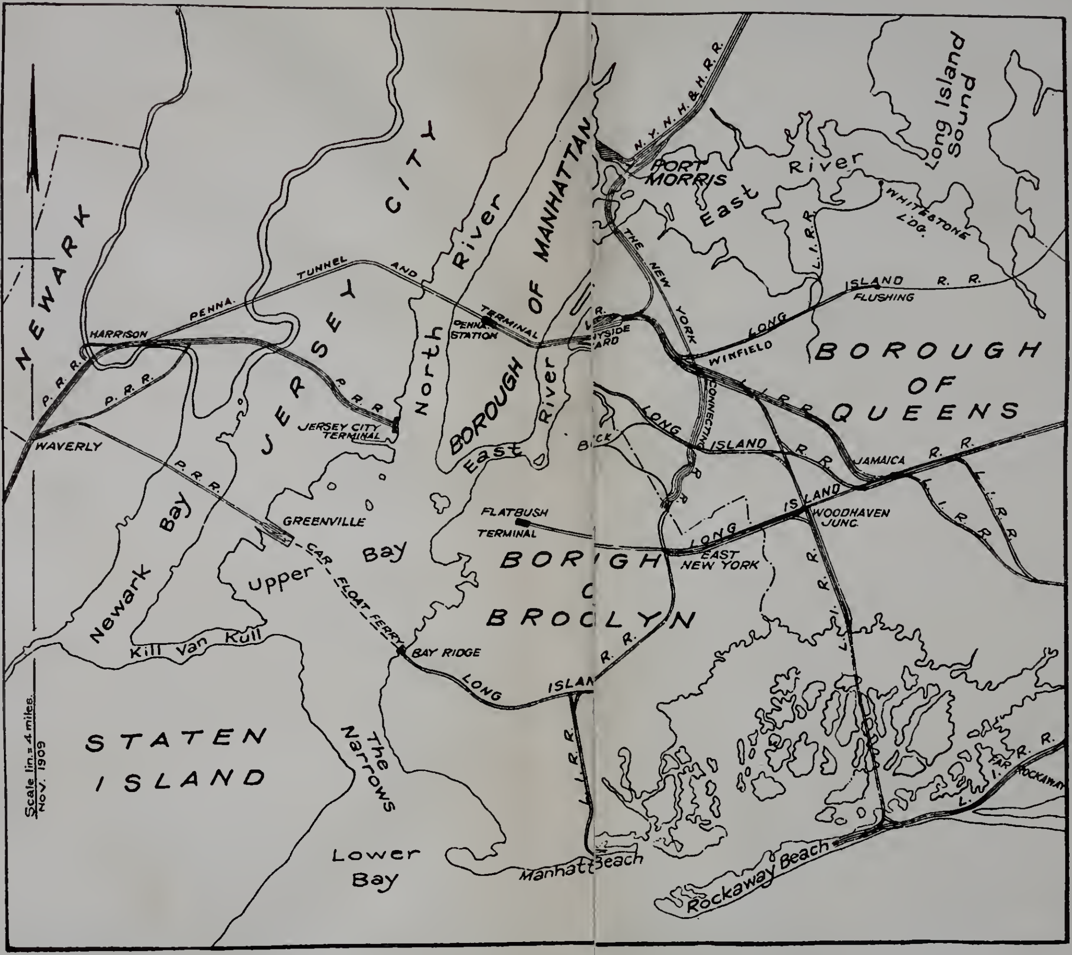
CAST IRON TUBE SECT
Scale 1"=6'

STEINWAY TUNNEL

UNDER EAST RIVER

From Fourth Avenue, Manhattan.
To 4th St. Long Island City, Queens.

PLATE 5.

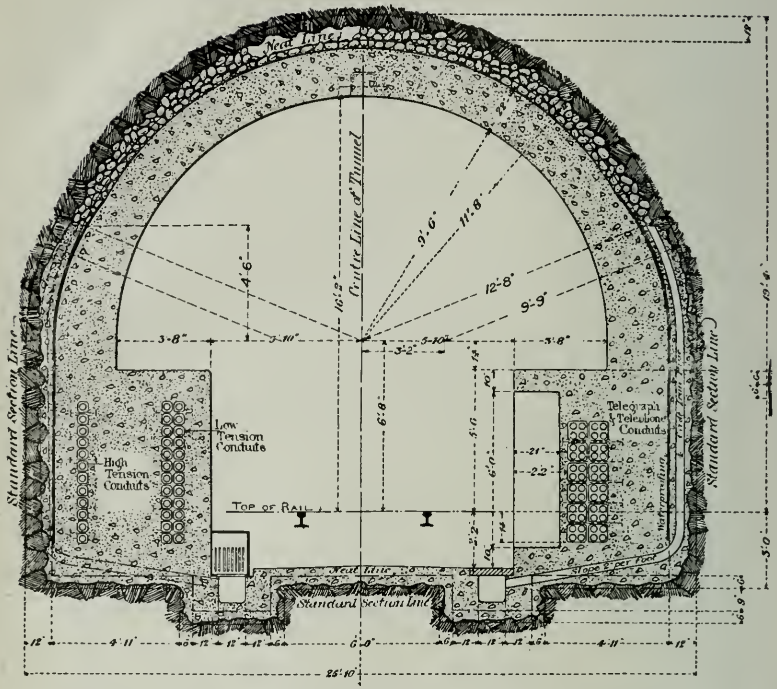

NEWARK
HARRISON
P. R. R.
P. R. R.
WAVERLY
P. R. R.
PENNA.
TUNNEL
AND
TERMINAL
JERSEY CITY
P. R. R.
JERSEY CITY TERMINAL
North River
PENNA. STATION
BOROUGH OF MANHATTAN
East River
Newark Bay
Newark Bay
GREENVILLE
Upper Bay
CAR FLOAT FERRY
BAY RIDGE
Kill Van Kull
STATEN ISLAND
The Narrows
Lower Bay
Manhatt Beach
Rockaway Beach
FAR ROCKAWAY
L. I. R. R.
N. Y. N. H. & H. R. R.
PORT MORRIS
East River
Long Island Sound
WHITESTONE LDG.
L. I. R. R.
LONG ISLAND R. R.
FLUSHING
WINFIELD
R.
YSIDE ARD
THE NEW YORK CONNECTING R. R.
BOROUGH OF QUEENS
L. I. R. R.
LONG ISLAND R. R.
JAMAICA R. R.
L. I. R. R.
L. I. R. R.
B CK
LONG ISLAND
WOODHAVEN JUNC.
EAST NEW YORK
L. I. R. R.
FLATBUSH TERMINAL
BOR GH
O
BRO LYN
R. R.
LONG ISLAN
L. I. R. R.
Scale 1in.=4 miles.
Nov. 1909.

Pennsylvania Railroad Terminal.

The project for a terminal on Manhattan Island was decided upon in the latter part of 1901, and surveys and preparations of plans were taken up at once. Construction was begun in 1903, and in 1910 the works were completed and put in use. The general features of the project may be outlined as follows:

Diverging from the former main line of the Pennsylvania Railroad at Harrison (Plate 5), about one-half mile east of Newark, a double-track railroad crosses the Hackensack Meadows on an embankment extending in a northeast direction, passing over other railroads, to the west face of the trap ridge known as Bergen Hill, which parallels the Hudson for several miles. The point where the line reaches Bergen Hill is nearly on the line of Thirty-second Street in New York City. Entering Hackensack portal, the two tracks pass under this hill in two single-track tunnels with a descending grade toward the river. A typical section and view of the completed tunnel are shown in Plate 6. The Bergen Hill section is about 6000 feet long. On the east face of the hill and about 1000 feet from the river is a large, open shaft across which the lines pass and enter the tunnels leading to and under the river to a point opposite a shaft near Eleventh Avenue in Manhattan, about 1300 feet east of the river bulkhead on the Manhattan side. The distance between the two shafts is about 6600 feet, about 4000 feet being under the water of the Hudson River. The maximum depth of the bottom of the tunnel below mean high tide is 96.9 feet. Except for a short distance from each shaft, the tunnels in this section are so-called tube tunnels and were built with the aid of shields. Eastward from Eleventh Avenue shaft the construction is twin-tunnel, so-called, this term being applied to the case where two tunnels are formed with concrete in a single excavation. This construction ends at the east side of Tenth Avenue, where the tracks enter the area of the station. From the river bulkhead to Tenth Avenue the tunnels are directly under Thirty-second Street. The station area extends eastward to Seventh Avenue, a distance of about one-half mile; eastward from Seventh Avenue the 21 station tracks converge into two three-track tunnels, one under Thirty-second Street, the other under Thirty-third Street. A typical cross-section and a view in the

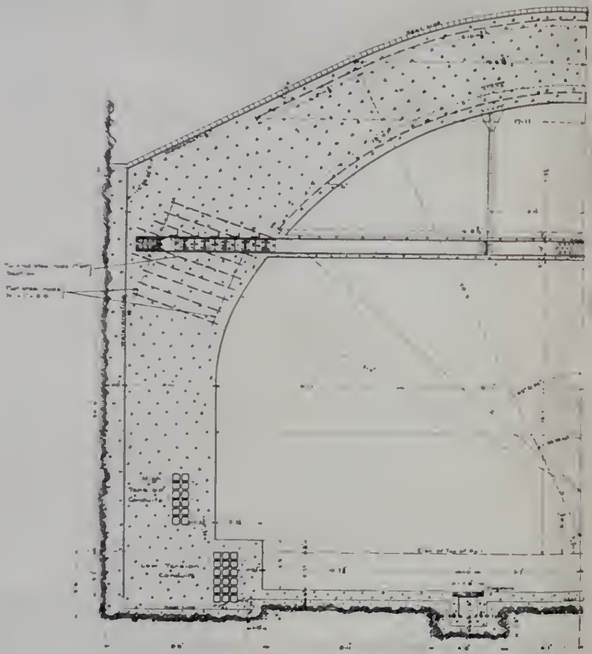
PLATE 6.



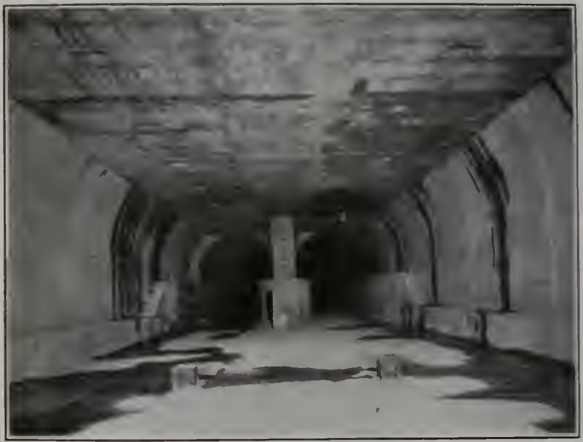
Cross-section, Bergen Hill tunnel.

View in Bergen Hill tunnel.

LATE 7.



Cross-section, three-track tunnel.



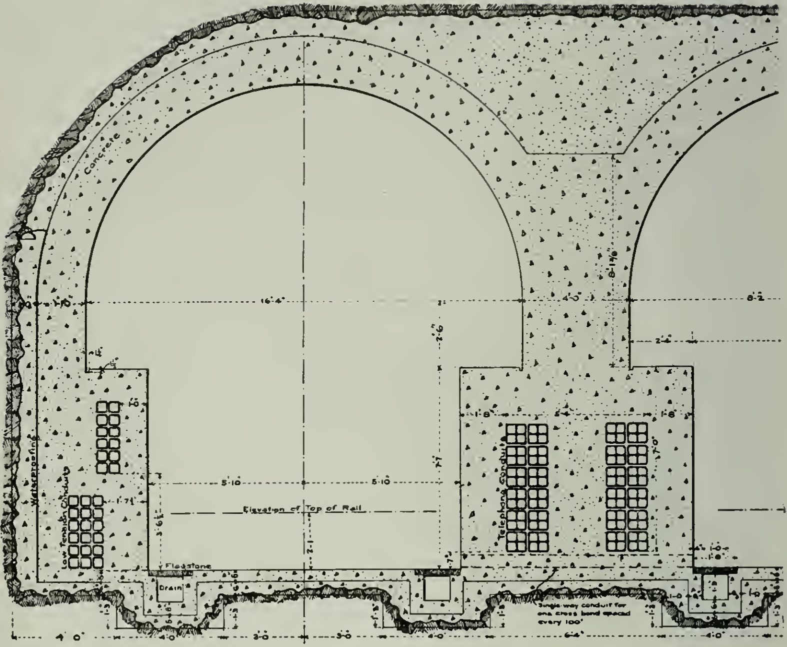
View in three-track tunnel.

completed tunnel are given on Plate 7. Near Sixth Avenue the construction under each street changes to twin-tunnel, as shown on the plate, the four single-track tunnels thus formed continuing to Second Avenue, where they curve to the left and pass diagonally under the built-up blocks, the distance between tracks of each pair diverging somewhat, so that the twin-tunnel construction ends and each tunnel passes into a separate excavation before arriving at the shafts near First Avenue. A typical cross-section of the twin tunnel and a view in the completed tunnel are given on Plate 8. At the First Avenue shafts the type of construction again changes to tube-tunnel, which continue under East River and about 2000 feet beyond, from which locality the tunnels were built in open-cutting to portals in Long Island City. The greatest depth of the bottom of the river tunnels below mean high tide is 91.3 feet. Eastward from the portals the tracks enter a large storage and car-cleaning yard. It will be noted that there are only two tunnels under the North River, while there are four under East River. The Thirty-second Street tunnels are for the use of the Pennsylvania Railroad trains arriving from the West; after discharging the passengers at the central station they continue eastward by the southerly tunnel to the yard in Long Island City, where the cars are cleaned and trains made up for the trip westward, proceeding to the station by the northerly Thirty-second Street tunnel. The two tunnels under Thirty-third Street are for the service of the Long Island Railroad.

The tunnels under Thirty-second and Thirty-third Streets pass under the existing subway line at Fourth Avenue with a clearance of some 36 feet, and the tracks in these tunnels are from 50 to 85 feet below street surface.

The tunnel system of the New York Terminal of the Pennsylvania Railroad, just outlined, comprises about 0.2 mile of three-track tunnels and 14.6 miles of single-track tunnels. Of the latter, 5.5 miles were shield-driven; 4.0 miles were driven by ordinary tunnelling methods as single-track tunnels; 3.6 miles by like methods for twin-tunnel construction; and 1.5 miles were built in open-cutting. All of these tunnels, except for a short distance near the westerly face of Bergen Hill, are below sea level, and this is also true as to the tracks in the station, the latter condition resulting from a franchise requirement that all

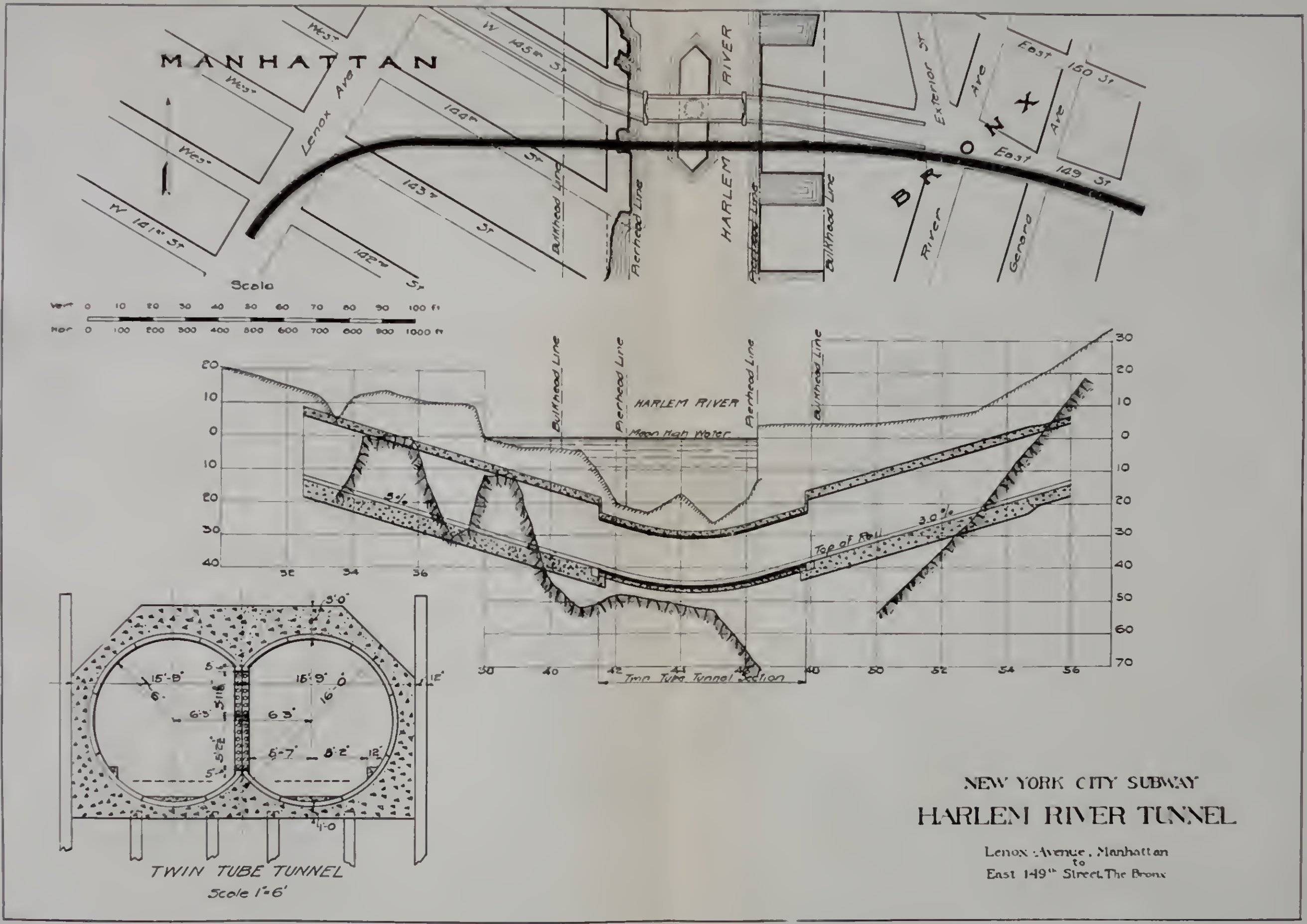
PLATE 8.



Cross-section, twin tunnel

View in twin tunnel.

PLATE 9.



NEW YORK CITY SUBWAY

HARLEM RIVER TUNNEL

Lenox Avenue, Manhattan
to
East 149th Street, The Bronx

parts of the structure under avenues must be at least 19 feet below the street surface, in order to permit the construction of subway railroads above them.

The several systems mentioned in the foregoing include six tunnels under Hudson River, eight under East River, and one under Harlem River. The tunnels under Hudson or North and East Rivers are single-track structures and were built in greater part by the shield method and by use of compressed air. The tunnel under the Harlem River is a twin-tunnel, for two tracks, the division wall being of cast iron.

CONSTRUCTION OF RIVER TUNNELS.

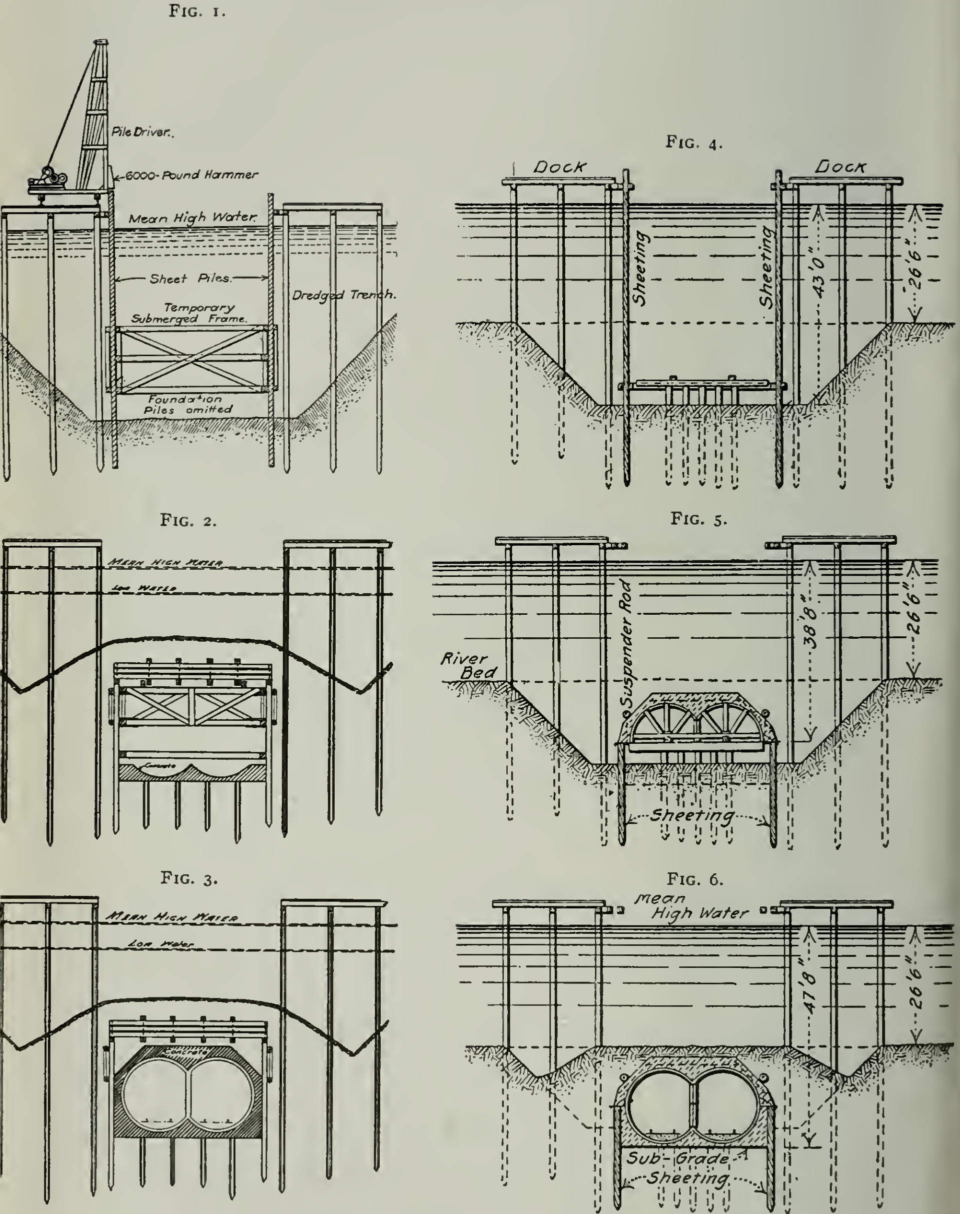
It may be said in a general way that three methods have been used in building the river tunnels: the first, in point of time (if we omit the earliest attempt of Haskin, which will be referred to further on), was the pilot-tube method, which was in use for a short time in a tunnel under the Hudson, the work being finally completed by the second, or shield, method, which has been adopted in all recent work in water-bearing materials under the rivers around Manhattan, except at the Harlem River tunnel, where the third method, devised and patented by the contractor, D. D. McBean, was used with success. Although this was one of the most recent works to be executed, it seems preferable to give a brief description of it in this place before dealing with the shield method by which the other fourteen tunnels were carried out.

The City Subway Tunnel Under Harlem River.

This tunnel connects the boroughs of Manhattan and The Bronx near 145th Street, Manhattan. A map, profile and cross-section are shown in Plate 9. The portion built by the method about to be outlined was 641 feet long. The depth of water required over the tunnel for navigation purposes was only 26 feet, which corresponded closely with the actual depth of water in mid-channel.

The contractor was permitted by the War Department to close one-half of the channel at a time. The Manhattan section was first taken in hand; three stages of the construction are shown in Figs. 1, 2 and 3 of Plate 10. The first step was to dredge a channel nearly to the full depth required for the con-

PLATE 10.



New York Subway System. Harlem River Tunnel.

struction of the tunnel; a staging or wharf on piles was then built along each side of the trench; foundation piles, spaced 6 feet 4 inches by 8 feet, were placed in the central portion of the trench and sawed off to an exact height. A strong frame, carrying guides for sheet piling, was then lowered on the piles and placed accurately. Walings attached to the wharf near the level of the deck also guided the sheet piling. The sheet piling was tongued and grooved and unusually heavy, and, being thoroughly guided while driving, was placed with great accuracy. The top of each row of sheet piling was sawed off accurately at a height slightly above that required for the finished tunnel, and a strong timber platform carrying shafts to admit men underneath was lowered on the top of the sheet piling and loaded with earth sufficiently to hold it down; the chamber underneath the platform was then completed by driving sheet piling across each end; compressed air was then put on, the water withdrawn from the chamber, and the excavation completed, the cast-iron lining built, and the enveloping concrete placed in compressed air.

In building the Bronx section the method was modified, as indicated in Figs. 4, 5 and 6 of Plate 10, by erecting the upper half of the cast-iron lining on a pontoon and placing the enveloping concrete upon it. The ends were closed by steel plate diaphragms. The pontoon was then sunk and withdrawn, the tunnel construction floating by reason of the air chamber; it was then loaded and lowered carefully on the sheet piling, forming the roof of the working chamber, and leaving only the lower half of the tunnel to be built in compressed air.

In this brief description many interesting details are necessarily unmentioned; but the work was a good example of a project carefully studied and each successive step made easy by the steps preceding.

Haskin's Tunnel Work under North River.

The first tunnel construction undertaken under either of the rivers surrounding Manhattan Island was at the New Jersey end of the north tube of the McAdoo uptown tunnels. Soon after 1870 Dewitt C. Haskin proposed to use compressed air for tunnelling in Hudson River silt, believing that by laying painted canvas against the silt to prevent air seepage through it the compressed air would support it and tunnelling would be easily done.

He was the first to use compressed air in any important tunnel, and believed the idea to be original with himself, but this appears to have been erroneous, for a compressed-air system for this purpose had been patented in England by Admiral Cockrane fifty years before. Haskin began work for two tunnels under the Hudson River in 1874 by sinking a shaft in Jersey City, but the work was held up by litigation for several years, and tunnelling in compressed air was not begun until 1879. Unfortunately, Haskin's method was not practicable in the soft silt or mud of the bed of Hudson River, and on one occasion, after several accidents of less importance, an inrush of mud occurred and several lives were lost. His superintendent, John Anderson, then devised the so-called pilot-tube method, which consisted in first driving a small tunnel about 6 feet in diameter along the axis of the larger one; this pilot tunnel was lined with plates bolted together at the edges, and was built to a length of 50 or 60 feet. The excavation was then carefully enlarged around the rear end of the pilot tube to the full size desired and lined with thin plates, which were supported by radial struts from the pilot tube. After thus enlarging the excavation for a short distance the brick tunnel lining was built in and the rear plates of the pilot tunnel were removed and carried through the tube and again built in at its front end. After many vicissitudes Haskin was finally obliged to stop, in 1888, after having built the north tube for a length of about 2000 feet and the south tube about 570 feet from the New Jersey side. He had also sunk a shaft in Morton Street, Manhattan, near the river bulkhead, and had built the north tunnel for a distance of 160 feet. The distance between the shafts was about 5700 feet, so that there remained to be built about 3500 feet in the north tunnel and about 5100 feet in the south tunnel. In the following year the enterprise was taken up by English capitalists and contractors and work resumed by the shield method; with the single exception before noted, this method has been used for all tunnelling in soft ground under both rivers since that time.

DEVELOPMENT OF SHIELD METHOD.

The development of the shield method of tunnelling has covered a period of nearly 100 years, but it is only within a comparatively recent period that the method has come into frequent

PLATE II.

FIG. 1.

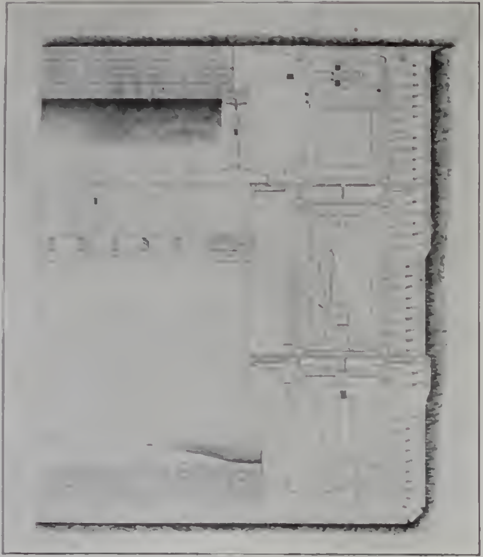


FIG. 2.

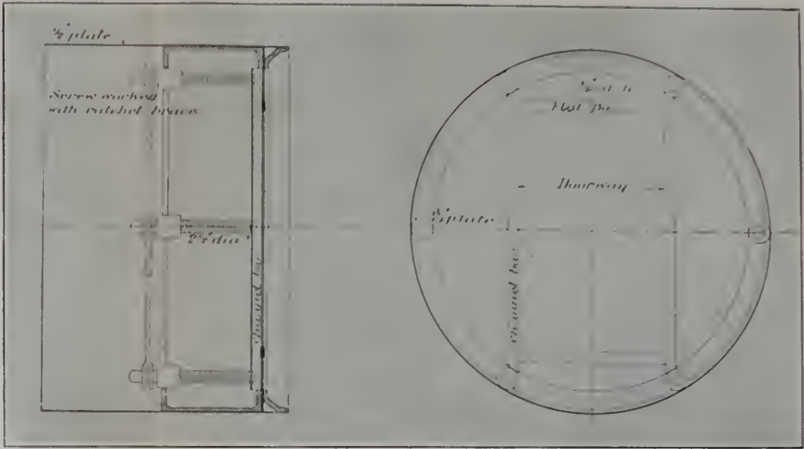


FIG. 3.

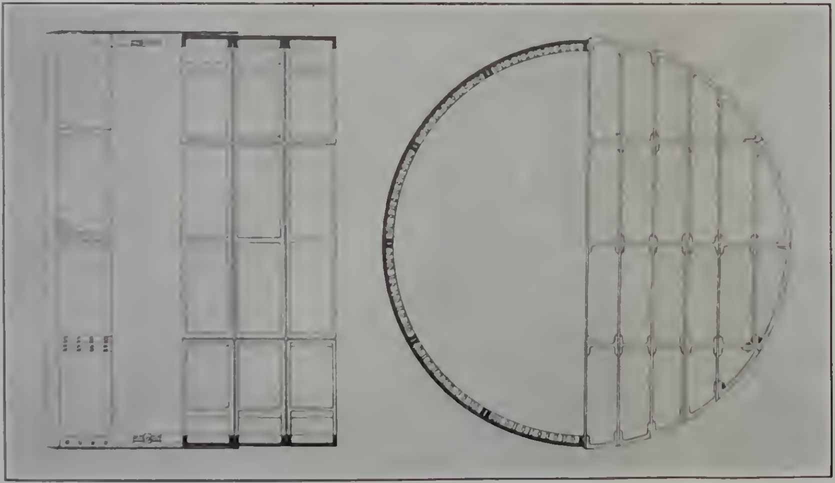
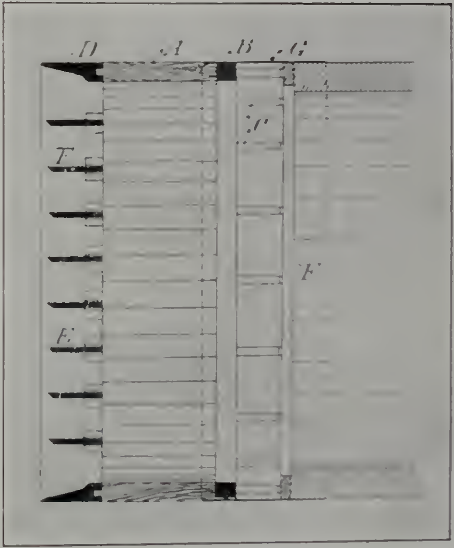


FIG. 4.



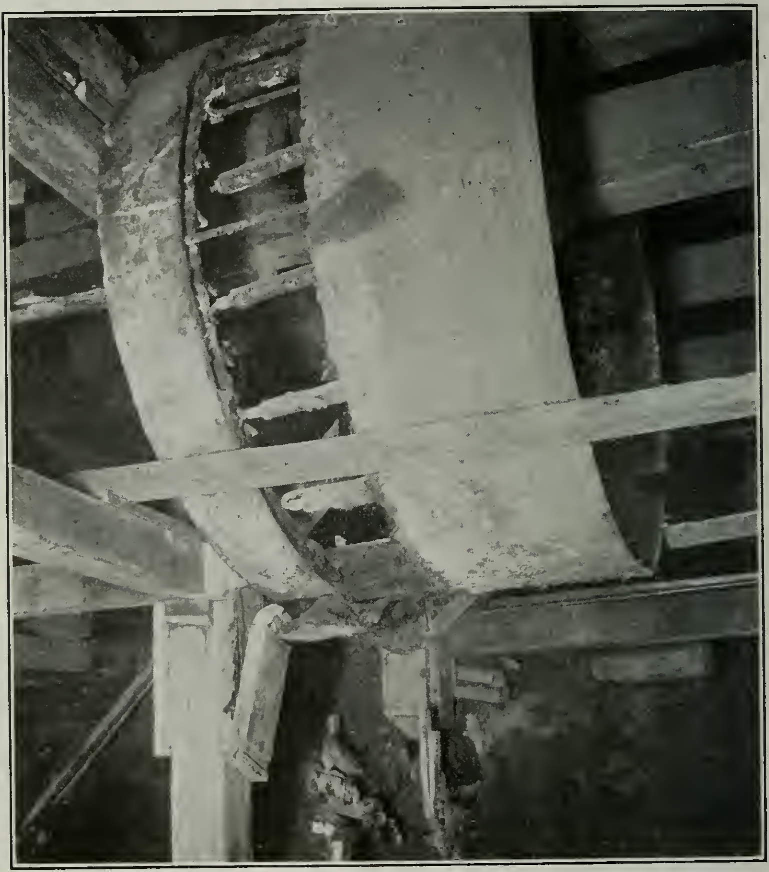
use. The first proposal for shield tunnelling, described in a British patent issued to Marc Isambard Brunel in 1818, included the essential features of modern shield tunnelling—a movable structure in advance of the completed tunnel, affording protection to the men at the face of the heading and provision for building the tunnel in short lengths inside the rear portion of the movable structure. Brunel's shield (Fig. 1, Plate 11) was composed of a large number of sections separately controlled. With such devices Brunel completed a tunnel under the Thames at London between the years 1828 and 1843. While the principles involved were much the same as in the shield of the modern type, there was little other resemblance.

The next important development was covered by a British patent issued to P. W. Barlow in 1864. The shield was to be a single structure and was essentially a cylinder a little larger in diameter than the tunnel (Fig. 2, Plate 11). As in Brunel's design, the tunnel was to be built up in short lengths within the rear portion, or tail, of the shield; the successive tunnel lengths were to be short, cylindrical iron rings. The shield was to be forced forward by means of screws. The use of hydraulic presses instead of screws to force the shield forward appears to have been first suggested by R. Morton, of Stockton-on-Tees, and is mentioned in a provisional patent issued to him in 1866. The use of the cast-iron cylindrical rings formed of segments, the segments and rings bolted together through inside flanges, is clearly defined in Morton's patent; the front of the shield, however, was to be (quoting the patent) "sharp or pointed like a wedge," an idea which has not yet been carried into practice.

Neither Barlow's nor Morton's shield was put into use, but a shield of similar type was designed, built, and used by J. H. Greathead in the construction of the Tower Subway under the Thames in 1869 (Fig. 3, Plate 11). This was the first tunnel built of cast iron, and has been the model for nearly all shield-driven tunnels built since that time.

In the meantime the subject had received attention on this side of the Atlantic, and in 1869 a shield designed by A. E. Beach was put into use and a short piece of tunnel built under Broadway, New York. In Beach's shield (Fig. 4, Plate 11), hydraulic presses were used for the first time to force the shield forward, antedating the use of hydraulic presses by Greathead in the construction of the City & South London Railway tunnel under the Thames by several years. There has been much dispute in regard to the respective claims made in behalf of Greathead and Beach as to priority in design and actual use of the modern tunnel shield; there is hardly room for question, however, that modern shield tunnelling owes more to Greathead than to anyone else.

PLATE 12.



Beach's shield.
Built 1869. Photographed 1912.

Beach's Broadway tunnel had been nearly forgotten until within the last year, when it was uncovered and removed in the building of a rapid transit subway. The shield was also found, the wood nearly all rotted away, but the metal portions and the hydraulic presses still intact (Plate 12).

The history of the development of the shield system of tunnelling during the ensuing thirty years need not be followed in detail. It will suffice for our present purpose to point out more definitely than I have done hitherto the principal features of the shield-driven tunnels as usually constructed and the essential parts of the shield by means of which they are built.

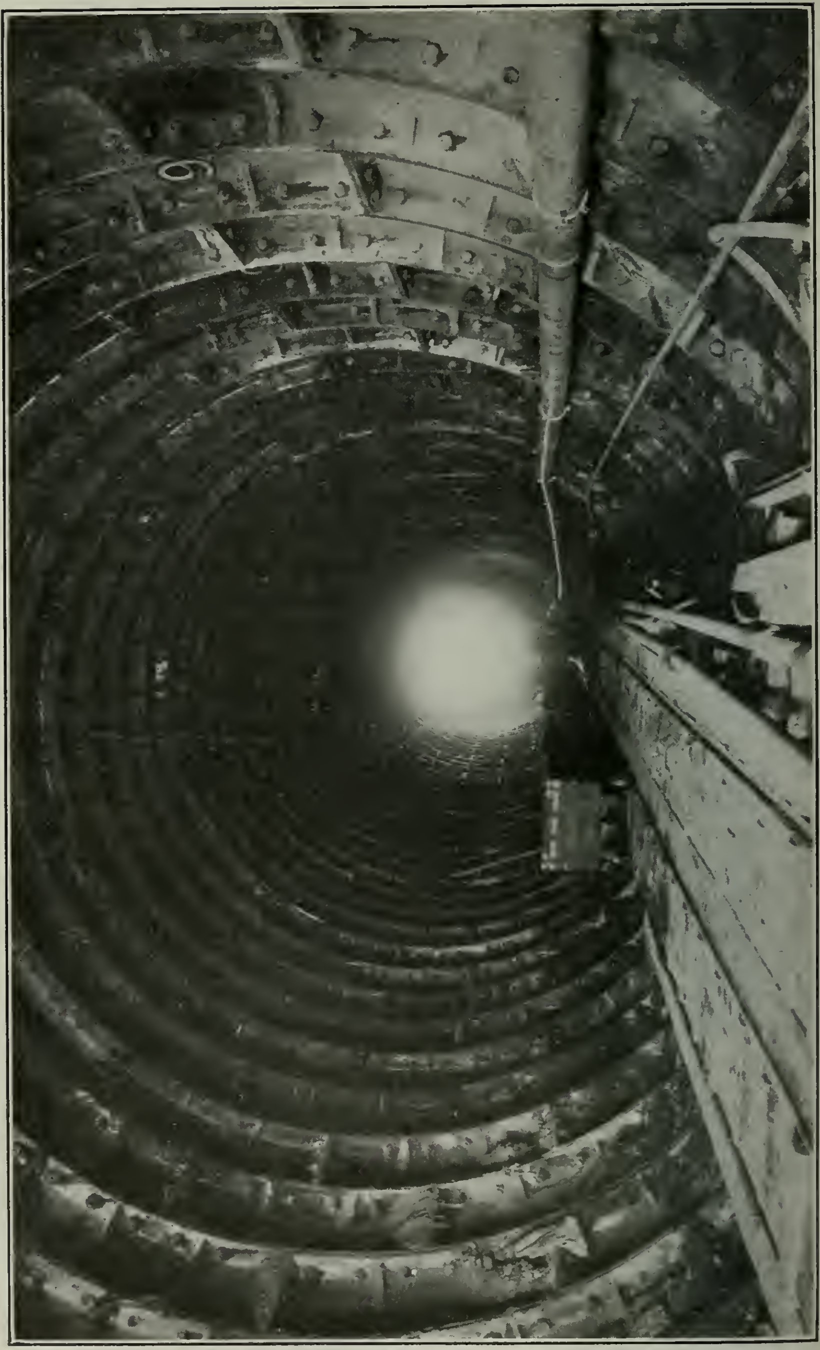
THE CAST-IRON TUBE.

The first stage in the construction of such a tunnel is to build the tube; this usually consists of cast-iron segments built into rings. Plate 13 shows the interior of such a tube, and Plate 14 shows details of the cast segments. The segments are 6 to 7 feet long, with radial joints, except a short closing segment or key in which the taper is reversed to facilitate building. Usually all meeting faces of the segments, including the joints between successive rings, are machined to true surfaces. The width of the rings varies in different tunnels from 18 to 30 inches. The segments and the rings are connected by bolts through inside flanges. Taper rings having a greater width on one side are used where it is desired to correct alignment or grade, or to pass along curves.

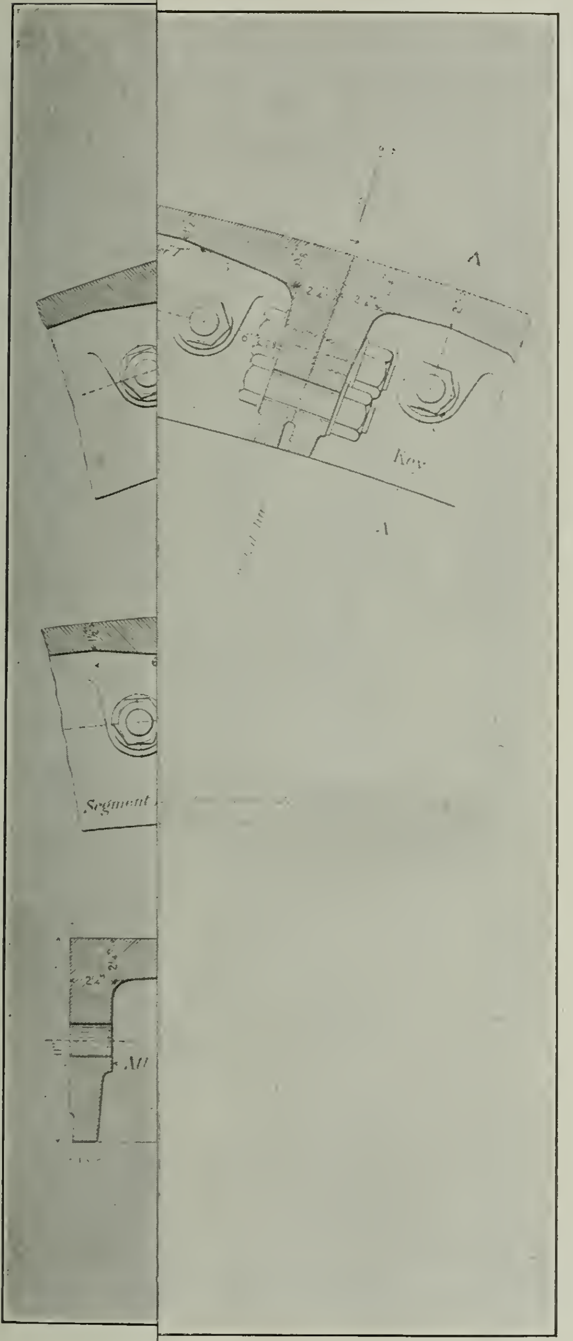
In the process of moulding a segment a rebate is formed around the inner edge of the side of the flange, resulting in a narrow but relatively deep groove after the segments are bolted together in the tunnel. In such material as the North River silt, which is nearly water-tight, a water-tight joint is secured by caulking ordinary rust-joint materials into the grooves. Where the material surrounding the tube is freely water-bearing the water filtering through the joints washes out the rusting ingredient before it has time to act, and rust-joint work is unsatisfactory. Better results are obtained by caulking lead into the joint, usually in the form of a rod or wire. After caulking the rod or wire into the bottom of the groove the remainder of the groove is filled with cement mortar.

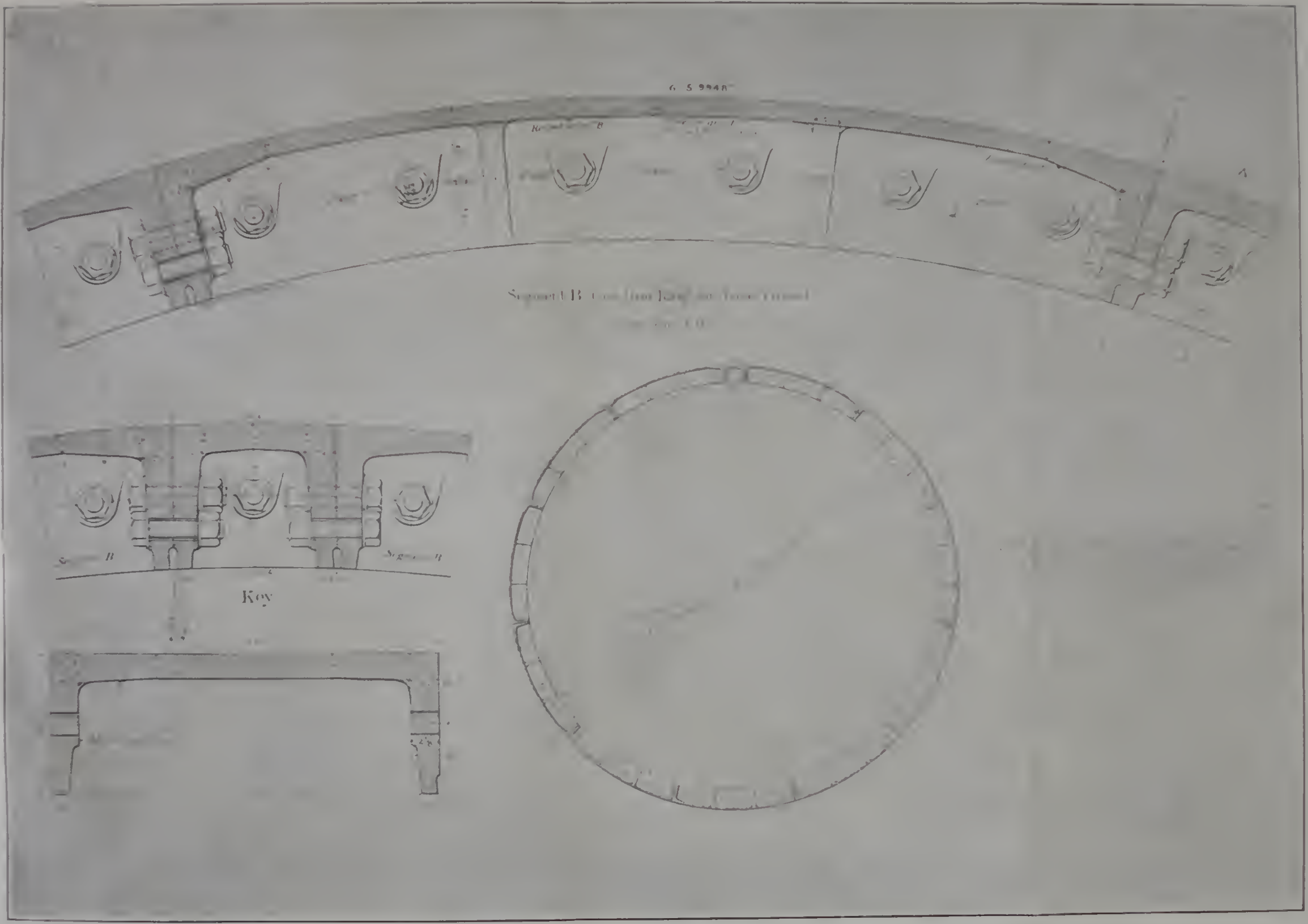
The bolt holes in the segments are cored considerably larger than the bolts to facilitate erection. They are usually made water-tight by grummets of hemp saturated with red lead and oil, or by winding the bolts with saturated hemp strand. These

PLATE 13.

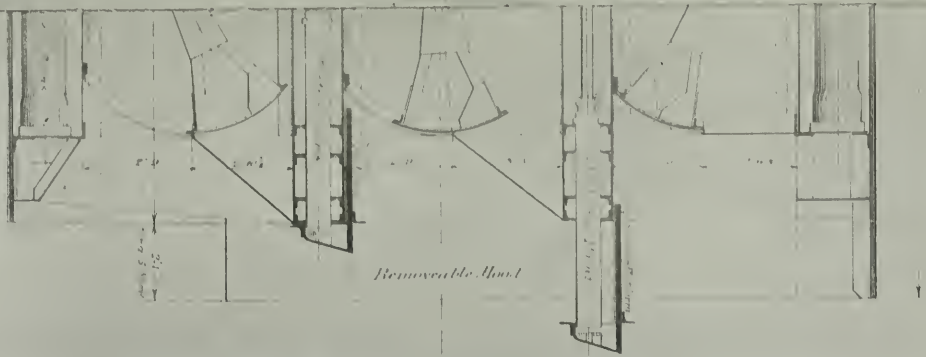


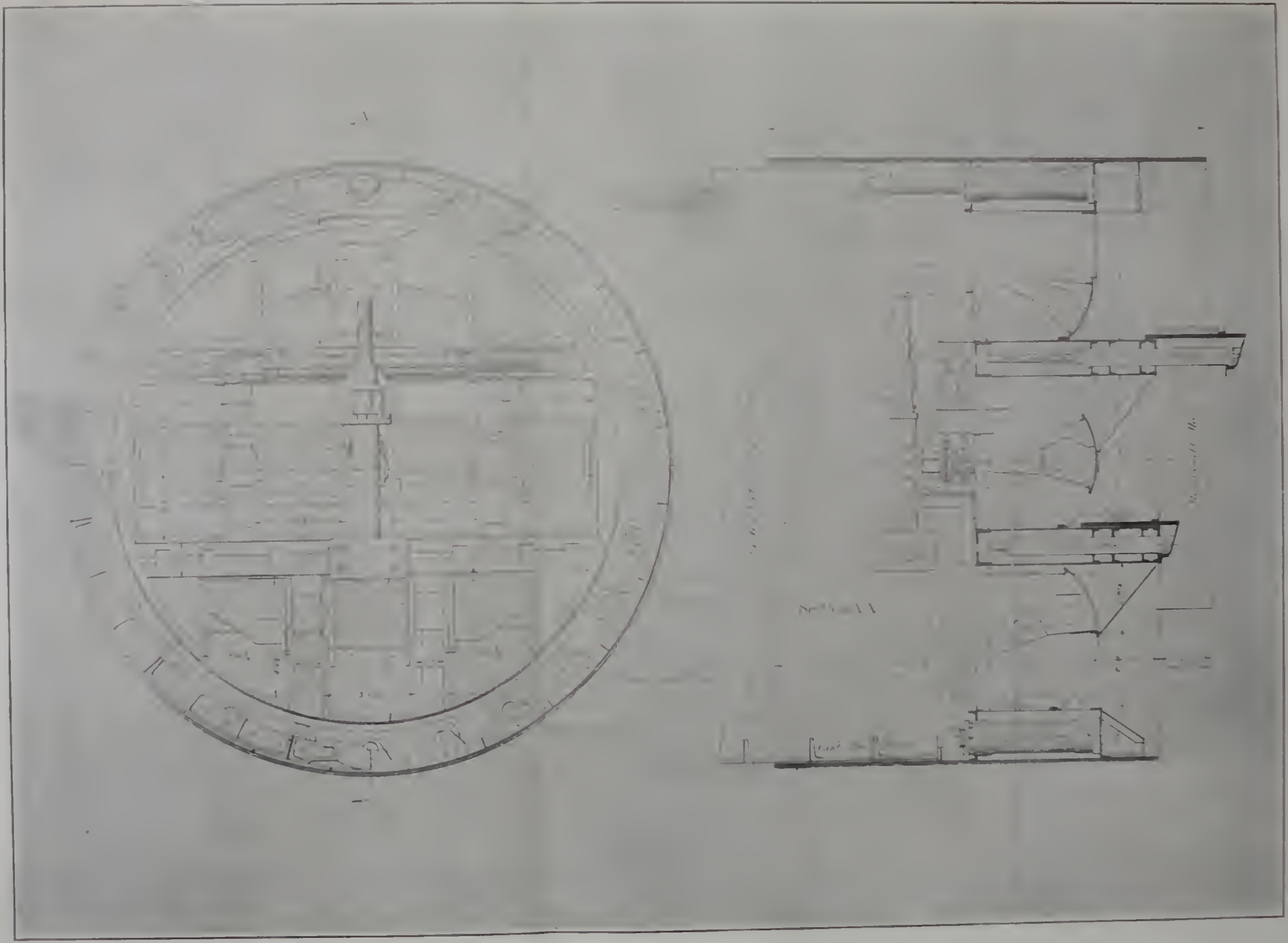
Interior of tube tunnel.


A
Key
A
Segment
All



Details of cast-iron linings.


Removeable Hood



Details of shield.

wrappings or grummets are placed between washers and the faces of the castings and afterward compressed when the bolts are tightened up.

It is probably not realized to what extent tunnel construction of this form has been carried out in connection with the tunnel systems referred to, the actual total being nearly 17 miles.

THE MODERN SHIELD.

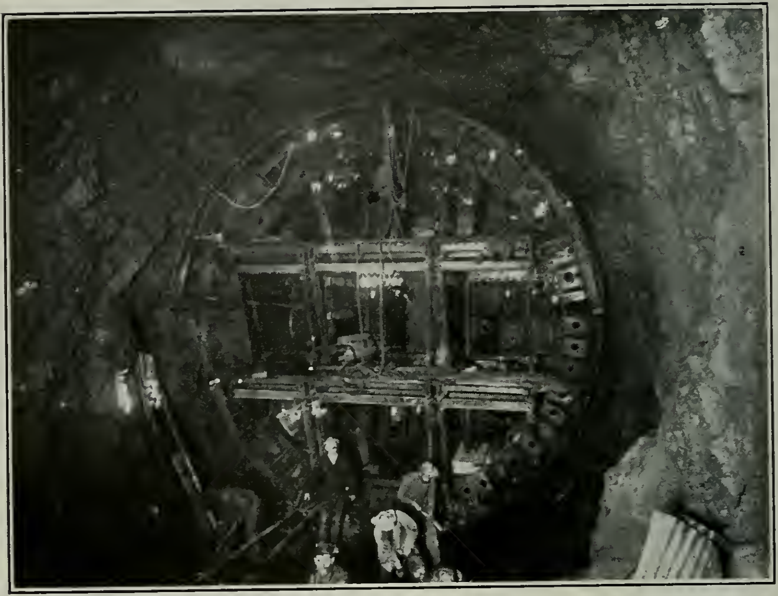
A shield may be defined as a short, movable length of tunnel, affording protection for excavating in the advancing face and for erecting successive rings of tunnel lining within the rear portion or tail. In the North River silt the shield could be pushed along without excavating in front, but in firmer materials, such as clay, sand, gravel, and rock, the shield must afford facilities for excavation before the shield can be advanced. The shield used in the Pennsylvania Railroad tunnels under North River is shown in sectional view on Plate 15. Front and rear views of a shield used in one of the Pennsylvania Railroad tunnels under East River are shown on Plate 16.

The structural portion of the shield may be considered as made up of three sections, as follows:

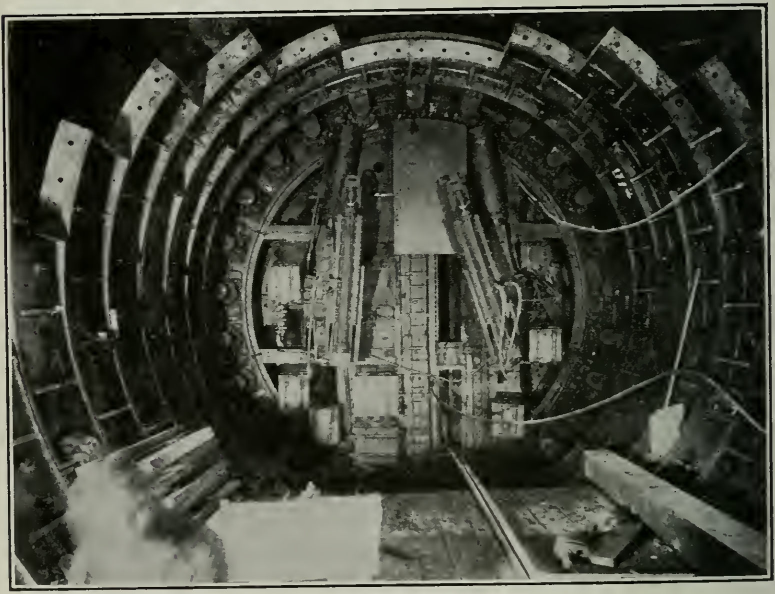
First.—The cutting edge, which for use in firm materials must be made very massive, as illustrated in the East River shields on Plate 16. In this shield the cutting edge was of heavy steel castings strongly connected with each other and with the cylindrical shell of the shield. This ring of heavy castings was continuous around the circumference of the shield, the projecting part shown in the upper portion, intended for use in sand, being temporarily attached to the true cutting edge. Such a heavy cutting edge was not needed in the silt of the North River, and the sectional view, Plate 15, shows a lighter construction.

Second.—The central portion or body of the shield carries an interior shell, concentric with the outer one, the two being connected by diaphragms or ribs forming longitudinal pockets, within which are placed the hydraulic jacks for pushing the shield forward. The circular girder formed by the two concentric and connected shells is further strengthened by one or more transverse plates or diaphragms connected all around with the circular girder, and (in the shield shown on Plate 16) by two horizontal floors and two vertical partitions, connected with the circular

PLATE 16.



Front of shield.



Rear of shield.

girder, the transverse diaphragm, and with each other. The number of floors and vertical partitions varies according to the dimensions of the shield. The body of the shield carries various devices for maintaining the face in soft ground, erectors for building the successive rings of the tube, etc. The transverse diaphragms has openings for passing men or materials. In the Hudson River shield shown on Plate 15 these openings were closed by swinging or "Taintor" gates. The hydraulic jacks take bearing against the face of the ring last erected (see Plate 16). After the shield has been pushed forward far enough to permit the erection of another ring of the tube, or, technically speaking, when the "shove" is completed, the jacks are closed, or "drawn home," leaving a space of sufficient width for the new ring.

Third.—The tail of the shield has no interior bracing. When the shield is in position for the erection of a new ring the tail should overlap the second ring back, as shown on Plate 16, in order to permit the removal of any broken segment in the ring last erected.

The resistance to the forward movement of the shield may be very great, and the equipment of hydraulic jacks in the New York tunnel shields could exert a pressure of 2000 to 6000 tons. When the material was rock, blasting was often carried on immediately in front of, and almost in contact with, the shield. Under such severe treatment some of the shields were much damaged.

The larger diameter of the shield as compared with that of the tunnel causes an annular void to be left immediately behind the shield sufficient to cause settlement at the surface of the ground, and, where the shield is driven under city streets, may cause injury to adjacent buildings. This result can usually be prevented, or at least minimized to a large extent, by forcing grout outside the lining through holes in the segments provided for this purpose, each hole being closed by a screw plug.

SHIELD TUNNELLING METHOD APPLIED IN NORTH RIVER.

The resumption of work in 1889 in the tunnels under North River begun by Dewitt C. Haskin, and the use of the shield method in continuing it, have been mentioned. This resumption related only to the north tube. The shield was of the Greathead type, and was built in Scotland; the tunnel work was under the immediate superintendency of E. W. Moir, then a young man beginning a career in tunnelling operations which has covered a large amount and wide range of difficult work. In this shield Greathead's earlier design was modified to better adapt it to the soft, flowing silt which forms the bed of North River, producing an effective tool with which a length of about 1900 feet of tunnel was built without serious difficulty of any kind; the work was then suspended for financial reasons and not again resumed until 1902, when it was taken up by the New York & New Jersey Railroad Company, the predecessor of the Hudson & Manhattan Railroad Company, under the general management of W. G. McAdoo, with Charles M. Jacobs as chief engineer. Moir's shield, after submergence for twelve years, was found to be in excellent condition, requiring only cleaning the machinery and slight repairs, and the river tunnel was completed with it.

THE MCADOO TUNNELS.

The problem of tunnelling through Hudson River silt had been substantially solved by Moir, but a new problem awaited, for soon after work was resumed in 1902 rock was encountered in the bottom of the excavation and continued for several hundred feet, and at its highest point was 15 feet above the bottom of the tunnel, giving nearly a full face of rock. While the tunnel was in silt but little excavation was necessary, and usually this could be made without going in front of the shield by opening a door or slide in the face of the shield and permitting the material to enter the tunnel; but when rock was met it was necessary to work in front of the shield in order to drill, blast, and remove it. The soft silt required support by timbering, which was usually practicable, but in one place where the silt was in a semi-fluid state this was found insufficient, and a novel scheme was tried—that of hardening the clay by heat. Blowpipes fed with kerosene were applied for eight hours, after which the clay was found solidified sufficiently to permit the work to be continued. After passing the rock, sand was encountered, and this continued until meeting the old tunnel extending westward from Haskin's Morton Street shaft. The work since resumption had occupied 505 days, during which 1625 feet of tube tunnel were built, an average of 3.2 feet per day. Haskin's bulkhead across his Manhattan heading was broken through March 11, 1904, thus completing the first tunnel under the Hudson River, about thirty years after it was begun.

The original project of Haskin was intended to provide for the passage of ordinary trains; the brick tunnel was 18 feet high inside and 16 feet wide, the cross-section being elliptical. The circular cast-iron tunnel subsequently built by Moir had a diameter of about 18 feet inside the flanges, giving an exterior diameter of about 19 feet 5 inches (Fig. 5, Plate 3), probably with the same traffic in view. When the New York & New Jersey Railroad Company took up the work, the Moir shield being still in place and usable, the north tunnel was completed with but slight change in diameters. This company, however, did not contemplate a tunnel system for ordinary railroad service, but for suburban trains with smaller cars, and therefore adopted smaller dimensions for the three remaining tunnels, reducing the exterior diameter to 16 feet 7 inches and the inside diameter, clear of the flanges, to 15 feet 2½ inches.[2] The exterior diameter of the new shields was 17 feet, a material reduction from the Moir shield, greatly facilitating pushing the shield through the North River mud, and while it became advisable, from time to time, to admit a small proportion of the material from the front of the shield into the tunnel, through the doors in the diaphragms of the shield, this only averaged about 5 per cent. of the amount displaced. The greatest caution was required in admitting this material on account of its semi-fluid character. When working alongside the coal wharf of the Delaware, Lackawanna & Western Railroad, where special care was needed to avoid injuring the wharf, the chief engineer issued stringent orders that the doors should be kept closed while the shield was moving forward. On one occasion a night superintendent, finding the shields moving very slowly, disobeyed orders and opened the door. The mud being compact and solidified required at first to be dragged through the opening. All went well for about half an hour, when suddenly a jet of silt of the cross-section of the opening shot through and buried one of the men, the remainder of the force escaping through the airlock some distance back in the tunnel. Within a short time the tunnel became solidly filled

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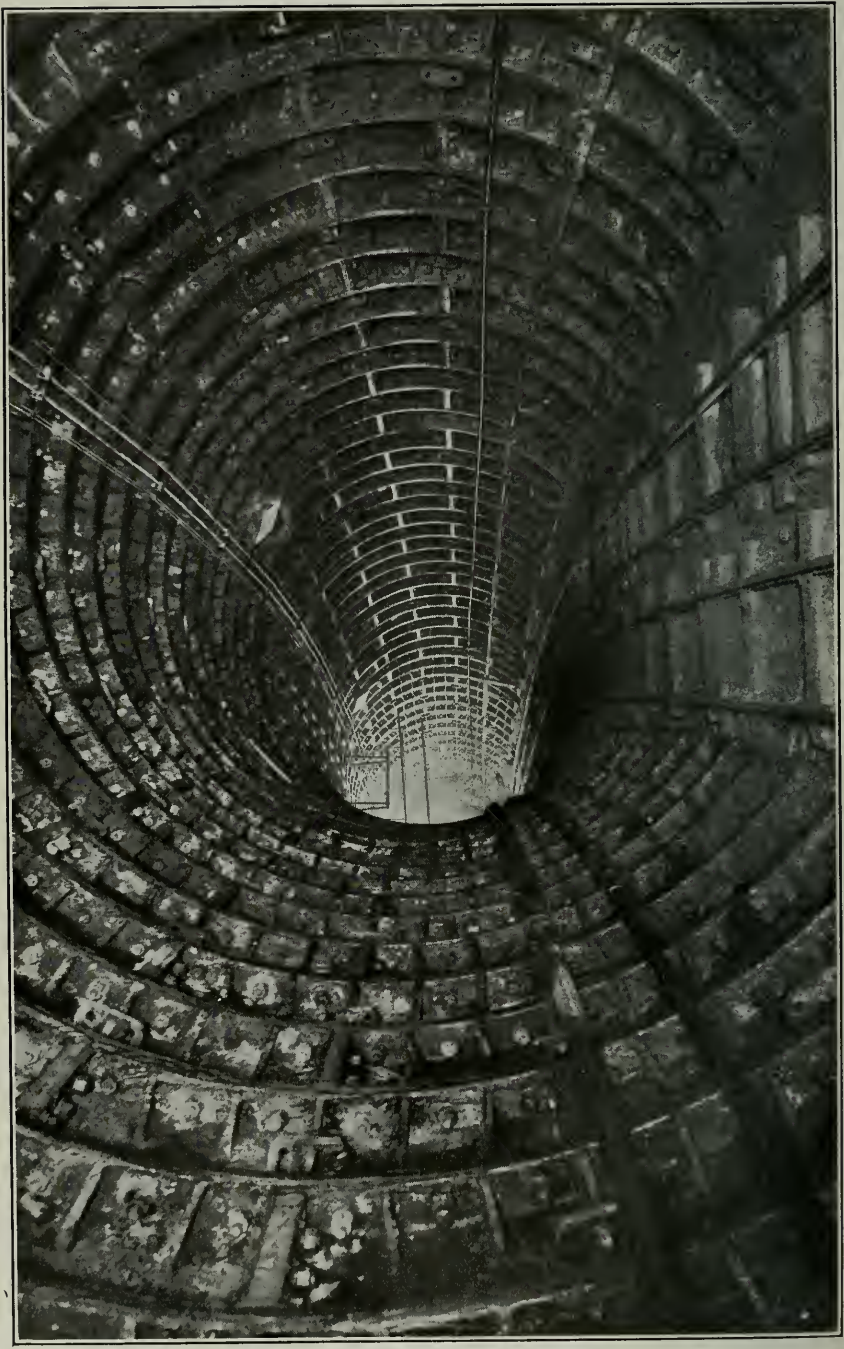
[2] For details of dimensions and weights of cast-iron lining see table on page 384.

PLATE 17.



Hudson & Manhattan Railroad. McAdoo tunnels. Morton Street curve.

with mud back to the bulkhead in which the airlocks were placed. In order to recover the tunnel, the bed of the river over the end of the tunnel and just ahead of it was covered with a large canvas of double thickness. A valve at the outer end of the pipe which extended through the airlock bulkhead was then opened and the mud shot out a distance of 40 feet, and cars were filled with it for eight days; as mud was thus withdrawn through the bulkhead the tunnel between the bulkhead and the shield was kept filled by the mud entering through the open door of the shield, gradually forming a depression in the river bed, which the canvas followed until it finally reached the door and blocked it, after which the men worked their way into the tunnel, compressed air was again put on, and in nine days more the shield was reached and the door closed.

As experience was gained mishaps became infrequent and progress through the mud became rapid. In one week 346 lineal feet of tunnel were built, and about 70 lineal feet were built in one day of 24 hours. There were difficulties when rock was met and also when passing through sand, similar to those to be referred to in connection with the tunnels of the Pennsylvania Railroad.

In driving the shields landward from the Morton Street shaft toward Sixth Avenue it was necessary to build some sharp curves; one of these of 150 feet radius is shown on Plate 17.

Typical cross-sections are shown on Plate 3. All of the tunnels except the north uptown tunnel are of the standard section shown in Fig. 4. The track is of the ballasted type, laid on a concrete floor, the concrete being extended far enough up the sides of the tube to enclose the ducts for the electric cables required for operating the railroad. The north uptown tunnel was built of larger section, as before mentioned, but the interior section brought to standard dimensions by an interior lining of concrete as shown in Fig. 5.

The uptown tunnels from Hoboken were opened for traffic to Nineteenth Street and Sixth Avenue in February, 1908, and to Thirty-third Street in November, 1910. The downtown tunnels were opened from Church Street to the Pennsylvania Railroad station in Jersey City and successive portions of lines paralleling the river were put in service at various times in 1909 and 1910.

THE NEW YORK CITY SUBWAY TUNNELS UNDER EAST RIVER BETWEEN MANHATTAN AND BROOKLYN.

The portions of the subway system here considered comprise two cast-iron tubes under East River from a point near South Ferry in Manhattan to the foot of Joralemon Street in Brooklyn, a distance of 4372 feet, and their extensions landward for a distance of 440 feet in Manhattan and 1978 feet in Brooklyn, making a total distance of 6790 feet, or 13,580 lineal feet of tube tunnel. A map, profile, and typical cross-section are shown on Plate 18. For the greater portion of their length under the river the tubes are 16 feet 8½ inches in diameter outside and 15 feet 5½ inches inside the flanges, and are of two types, one weighing 4545 pounds per lineal feet of tunnel, the other 5133 pounds. Somewhat heavier metal is used under the river bulkheads. In rock a lighter section is used, weighing 3992 pounds per lineal feet of tunnel, and is intended mainly for waterproofing.[3] In Brooklyn the same lighter section is used in the tubes above tide level. The tunnels were begun in 1903 and completed in 1907.

Tunnelling in the rock from the Manhattan side presented no marked features, but the earth presented two troublesome types: a rather coarse sand on the Brooklyn side and an extremely fine quicksand in the middle of the river. The difficulties met in passing through the quicksand were duplicated in the construction of the Pennsylvania Railroad tunnels, and will be described more fully in connection with that work. On the Manhattan side the tunnels in rock were built in air of normal pressure until the river front was passed, when airlock bulkheads were built across the tunnels and the compressed air was put on. Toward the middle of the river, near the point where the rock surface was broken through, shields were erected and tunnelling was continued out of the rock and into the earth to the points of junction with the Brooklyn shields.

On the Brooklyn side two shafts, one for each tube, were sunk at the points where the tubes rise above tide level, about 2000 feet eastward from the water front; shields were erected and started eastward in the dry headings, after which two other

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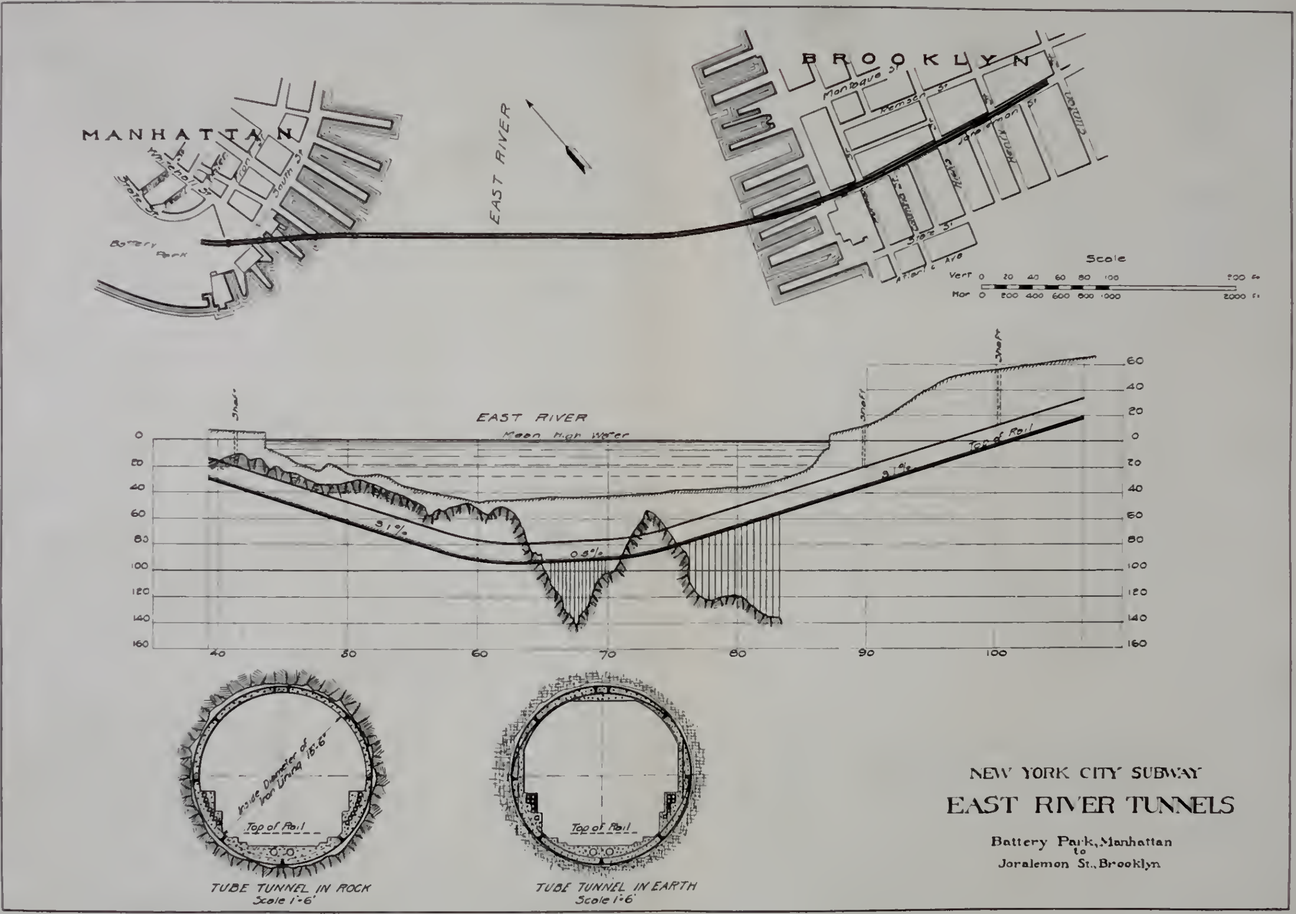
[3] For details of dimensions and weights of cast-iron lining see table on page 384.

PLATE 18.



TUBE TUNNEL IN ROCK
Scale 1"=6'

TUBE TUNNEL IN EARTH
Scale 1"=6'

NEW YORK CITY SUBWAY

EAST RIVER TUNNELS

Battery Park, Manhattan
to
Joralemon St., Brooklyn

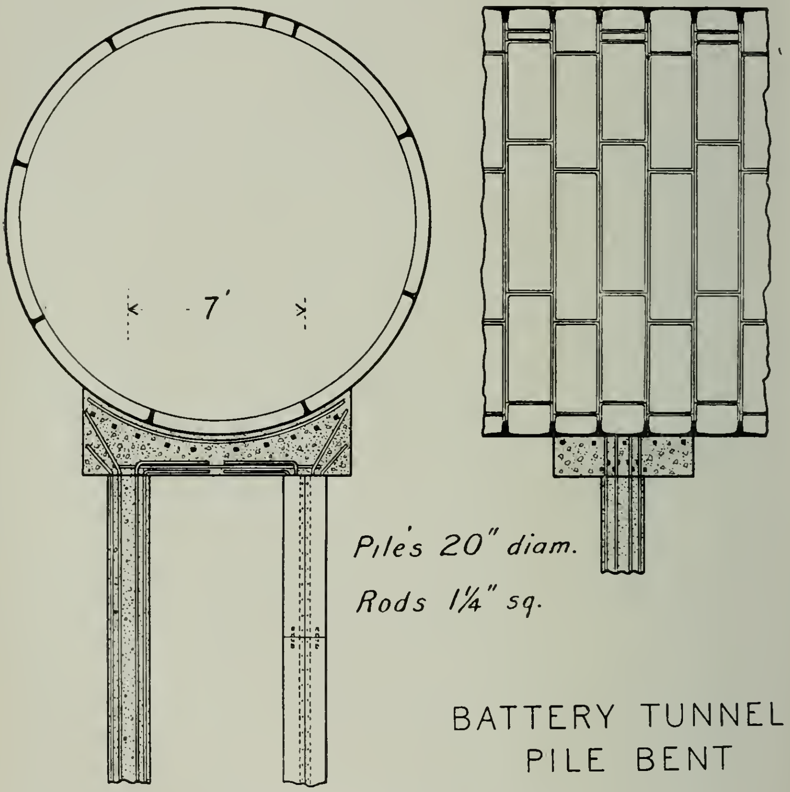
shields were erected in the same shafts and driven westward to the points of junction with the Manhattan shields.

Tunnelling in quicksand was a new problem met here and in the Pennsylvania Railroad tunnels almost simultaneously. In places the shield settled below the proper grade line, and in some places the changes in grade were too sharp for convenient operation of trains. The diameter of the tunnel gave so little leeway for trains that it was necessary to depress the bottom or to raise the roof of the tunnel so as to permit easier vertical curves in laying the track. In quicksand these were extremely hazardous operations unless done with the greatest care and skill. The lowering of the bottom of the tunnel was accomplished by first raising the air pressure enough to dry the underlying material when exposed and successively removing the cast-iron segments in the lower half of the tube, replacing them with new segments curved to an elliptical form so as to give a greater vertical diameter and therefore a lower bottom. This was a less hazardous operation than to raise the roof, and was the method generally adopted in the reconstruction. For a short distance in each tunnel the roof was actually raised by powerful hydraulic jacks sufficiently to permit the construction of a new masonry roof with a greater vertical clearance.

During the construction of these tunnels in the section where quicksand was encountered sensational articles appeared in the newspapers alleging the impossibility of maintaining the tunnels in position under traffic, and it is to be regretted that this alarm was promoted by a few engineers. It was finally decided, although believed unnecessary by the city's engineers, to support the tunnels in quicksand by means of concrete columns or piles. In order to place them the bottom segments of the tunnels were removed at intervals of 30 to 50 feet and the piles sunk by use of the hydraulic jet to harder materials at depths ranging from 5 to 75 feet. They were placed in pairs 7 feet apart transversely to the tunnel and their tops connected after sinking by reinforced concrete cradles conforming to the transverse outline of the tunnel. The cast-iron segments were then replaced, and the tunnel rested, more or less completely, on the cradles. About 1200 lineal feet of each tunnel were thus underpinned (Plate 19).

Since this work was done, the Pennsylvania Railroad tunnels under the East River, passing through similar material and unsupported except by the earth itself, have been in operation for about two years without the slightest settlement. The subway tunnel weighs considerably less than an equal volume of water; when filled with a train the weight is almost the same as that of an equal volume of water, and therefore much less than the displaced saturated earth. The Pennsylvania Railroad tunnels, with heavier construction, weigh somewhat more per lineal foot when loaded with a train than the displaced earth, and the tendency to settle would seem to be greater. It is well known that quicksand, when confined, will carry heavy loads without yielding, and, in fact, some of the high buildings in New York rest upon material undistinguishable from the river

PLATE 19.



New York City subway tunnels. Pile supports.

quicksand. In view of all this there is no room for doubt that the opinion of the city's engineers was correct.

The cast-iron lining in the city's tunnels was of lighter section than in the McAdoo tunnels, the latter being about 25 per cent. heavier. This is compensated for by strongly reinforcing the concrete lining where the tunnel is in earth under the river, where the pressure upon it is the greatest. The tunnels were opened for traffic in January, 1908.

PENNSYLVANIA RAILROAD TUNNELS UNDER NORTH RIVER.

A map, profile, and typical cross-section of these tunnels are shown on Plate 20.

For some distance from the shafts on both sides of the river the tunnels are in rock and were driven in normal air by ordinary methods. When the excavation in each tunnel had arrived near the point where the tunnel would pass out of rock into earth it was enlarged sufficiently to permit the erection of the shield; there were four shields for the North River tunnels, one in each tunnel on each side of the river (Plate 15). They were designed under the direction of Charles M. Jacobs, chief engineer of the North River Division. As they were to be driven through silt they were somewhat less massive and powerful than those for East River, where the materials ranged from quicksand to gravel, boulders, and rock. Still, the large tunnel dimensions adopted by the railroad company, the exterior diameter of the tube being 23 feet,[4] resulted in a very heavy shield, weighing, with all its accessories, 193 tons. To force it forward in the tunnel 24 hydraulic jacks were provided, capable of exerting a push of about 3300 tons.

After building the shield a concrete bulkhead was built across the tunnel behind it, containing three airlocks, two near the floor level through which the excavated materials were passed out and cast-iron tunnel lining, cement, and other material for construction were passed in. A third airlock was placed in the upper portion of the bulkhead for the use of the working force entering or leaving the tunnel. Each airlock was a steel tube about 7 feet in diameter and 20 to 25 feet long, with a door at each end opening toward the tunnel and air tight when closed. The bulkhead also contained smaller airlocks for passing pipe and similar materials into or out of the tunnel, pipe for compressed air, for water under pressure to operate the shield jacks, electric light wires, etc.

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[4] For details of dimensions and weights of the cast-iron lining see table on page 384.

After the bulkhead was completed compressed air was admitted to the tunnel and the advance of the tunnel excavation continued. The passing from rock to earth was a critical stage, when the danger of an inrush of earth was particularly great.

The first application of compressed air in these tunnels was in June, 1905. Prior to this the north tunnel of the uptown McAdoo tunnels had been completed under the river and a trained force was available for the Pennsylvania tunnels.

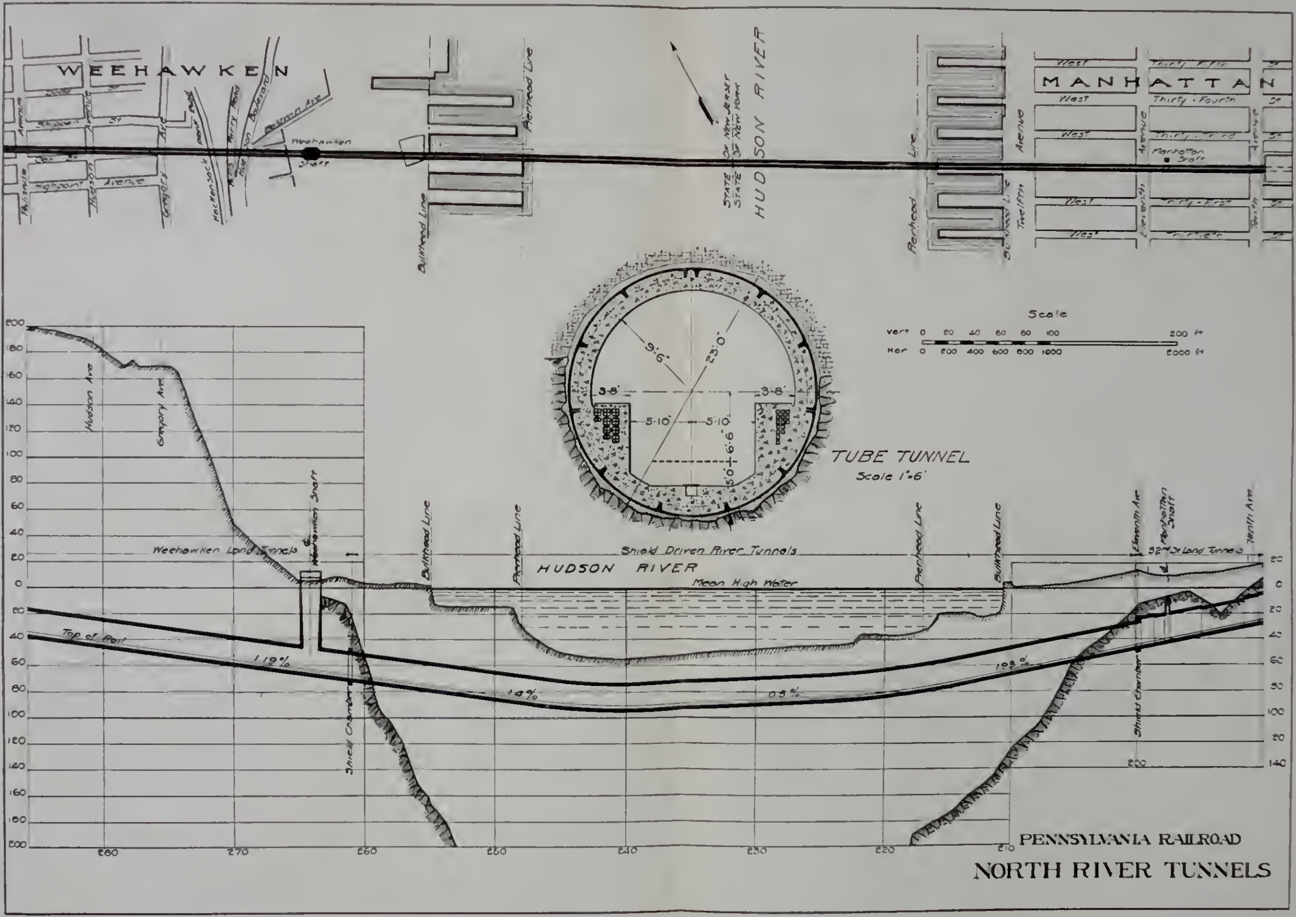
After passing out of rock and entering silt or mud it was seldom necessary to go in front of the shields. The hydraulic jacks could exert sufficient pressure to force the shield through the mud, but it was found impossible to keep the shield down to grade unless a portion of the mud in front was received into the tunnel. The portion required was, on an average, about 33 per cent. The principal office of the diaphragm, therefore, aside from the important one of stiffening the cylinder of the shield, was to furnish suitable openings for the admission of mud and sure means of closing them when desired.

Each shield was provided with one erector. It rotated on an axis on the centre line of the shield, in a plane normal to the tunnel and corresponding with the middle of the ring to be erected. It was rotated by a chain gear moved by two hydraulic rams. The erector itself was a hydraulic ram with devices for attaching the end of the piston rod to a segment to be erected. A segment could thus be picked up, the erector rotated, and the segment pushed into place by the erector.

With a suitable shield and an experienced working force the operation of tunnelling under the North River became mainly one of erecting tunnel lining, and the men became very proficient. A ring was frequently erected in 30 minutes; the maximum day's work was 15 rings, or 37½ lineal feet of tunnel, done in two 8-hour shifts. One gang working eight hours erected 8 rings, or 20 lineal feet of tunnel. They promptly advertised as the "8-ring gang," and were in evidence on exhibition occasions.

It was not necessary in North River mud to raise the air pressure to meet the full hydraulic head except when working

Plate 20.



PENNSYLVANIA RAILROAD

NORTH RIVER TUNNELS

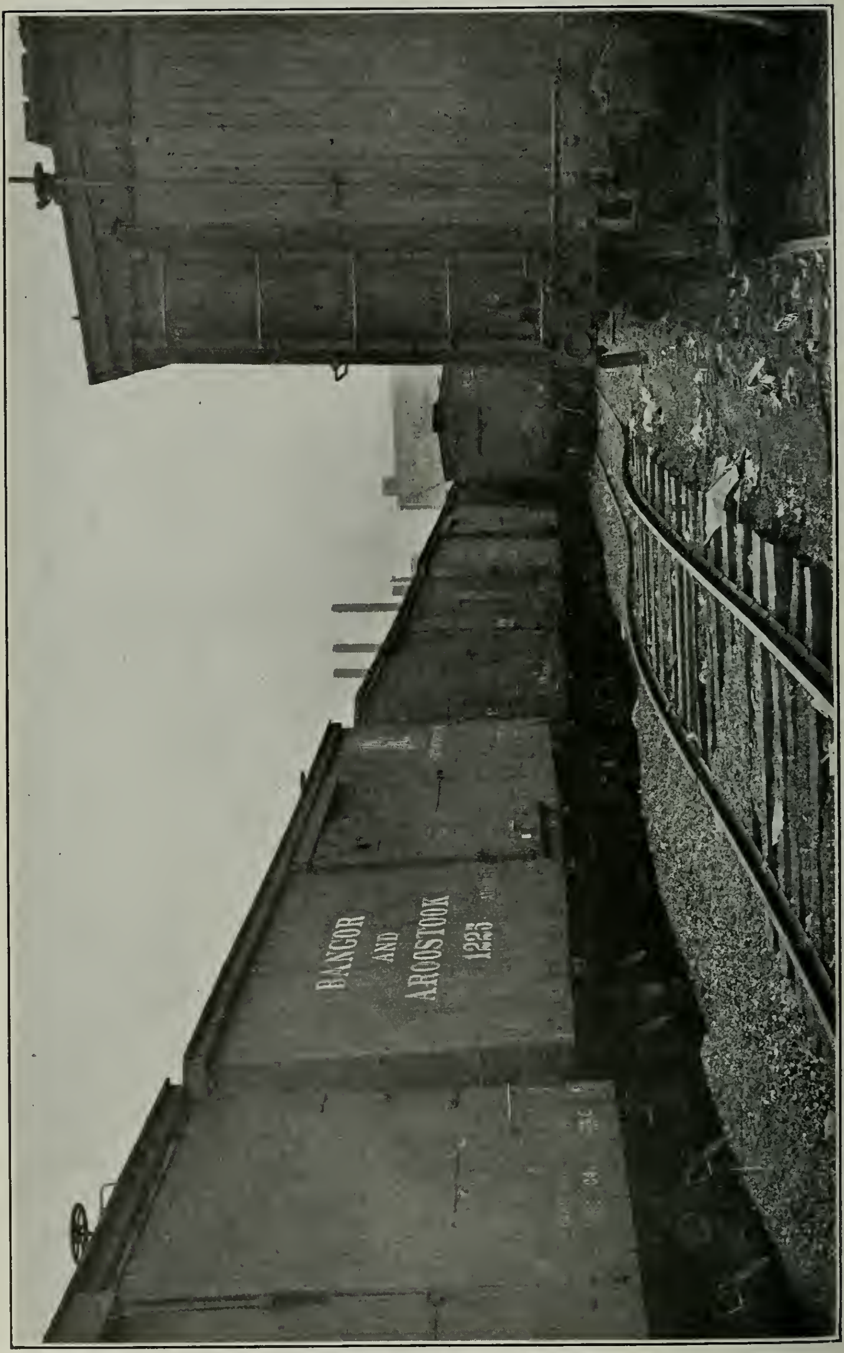
outside the diaphragm, as, for example, when cutting off piles projecting below the top of the shield. In such cases the pressure would be raised, effecting a stiffening of the mud and making it practicable to excavate a small volume, protecting carefully by timbering, and to remove the obstruction.

On account of the low air pressure usually carried, "blows," so-called, were infrequent. These are among the most picturesque, costly, and hazardous incidents of shield tunnelling. They can be dealt with more appropriately in connection with the East River tunnels, where they occurred with appalling frequency.

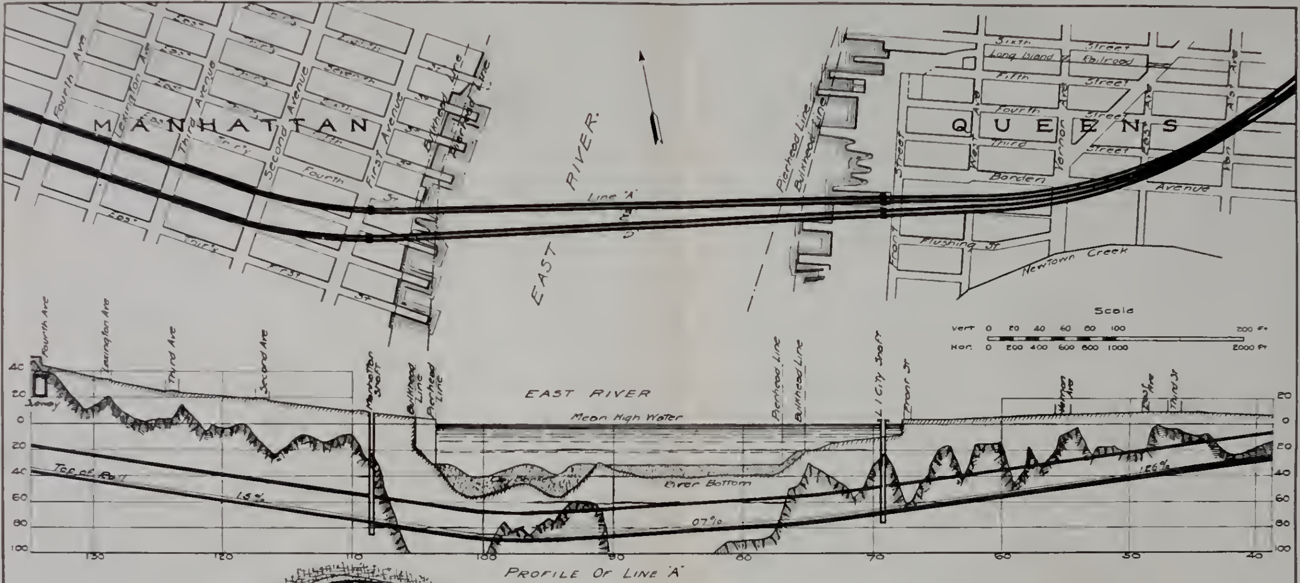
Pushing the shield through the mud without excavating the full tunnel displacement resulted in a ridge along the bed of the river over the tunnel lines as revealed by soundings. For some distance eastward from the river bulkhead on the Manhattan side the tunnels were driven under a freight yard of the New York Central Railroad, with the result of lifting the surface, which was some 50 feet above the tunnel (Plate 21).

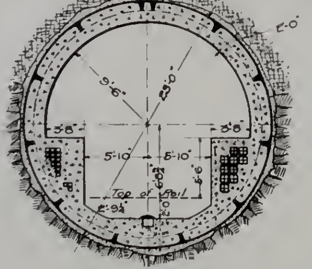
During a period of many years preceding the inauguration of traffic through the uptown tunnels of the McAdoo system there was much discussion in regard to the stability of tunnels in the North River mud. They were to sink in the mud; when it was pointed out that the cast-iron tubes weighed less than the displaced mud, or less, even, than the same volume of water, then the mud was said to be a viscous fluid through which the tubes would certainly rise. It was even urged that the bed of the river was a mass of flowing mud gradually but surely moving into the upper bay. These views were little affected by the fact that the Haskin-Moir tunnel had neither risen nor moved down stream, so far as could be ascertained. Still, it seemed possible that the condition of the material might change under the vibration set up by traffic, being more liquefied and causing the tunnels to rise or sink—views differed as to the direction. In order to meet this contingency plans were made to sink screw piles through the bottom of the tube, and their sufficiency either to carry loads or to serve as anchors fully tested by experiment. Before it became necessary to place them in the due progress of the work the uptown McAdoo tunnels had been in operation for several months without any of the dire results apprehended, giving confidence that the supports would not be required, and they were omitted.

PLATE 21



Surface of ground lifted by shield.





TUBE TUNNEL
Scale 1"-6'

PENNSYLVANIA RAILROAD

EAST RIVER TUNNELS

PENNSYLVANIA RAILROAD TUNNELS UNDER EAST RIVER.

The materials met with under East River were very different from those just referred to. For about half the distance under the river the excavation was in sand, with a little clay, mostly quicksand (Plate 22). Rock, wherever met, was overlaid by a few feet of gravelly material freely water-bearing. Here were practically two new problems: one where the excavation was partly in rock with open gravel over it. At the Blackwall tunnel under the Thames, built a few years before, the excavation was in gravel, but was not complicated by blasting rock, which in East River frequently brought down the timbering by which the face above was protected. A face partly in rock was met previously, as already mentioned, in the north tube of the uptown McAdoo tunnel in 1903, but the overlying material held air better. The other problem—tunnelling in quicksand—was far more difficult. These problems were being met almost simultaneously in the city tunnels between South Ferry and Brooklyn, but were less difficult there because of the smaller diameter of the tunnels and the lighter shields. The increase of diameter from about 17 feet in the McAdoo and city tunnels to 23 feet[5] in the Pennsylvania Railroad tunnels nearly doubled the area to be excavated; the weight of metal in the lining and the amount of compressed air required increased even more.

The shields were designed under the direction of E. W. Moir, a member of the same contracting firm for whom as engineer he designed the shield used in the North River tunnel in 1889. They were massive, weighing about 270 tons each when fully equipped, and cost about $44,000 each. The cutting edge was made up of heavy steel castings, as already described. There were 27 hydraulic jacks, each 9 inches in diameter, to move the shields forward. A push of 5600 tons has been exerted, but under ordinary circumstances 3000 to 4000 tons were sufficient. Each shield carried two erectors. Because of the unprecedented conditions many ingenious devices were provided to facilitate the excavation. When put in use they failed quickly, and simpler and stronger devices were adopted.

The tunnels approaching the river from the central station were in pairs, one pair under Thirty-second Street, the other under Thirty-third Street, as already explained. At the working shafts near the river on the Manhattan side the tunnels of each pair were 11 feet apart, and at the Long Island City shafts 14 feet apart. It was convenient, therefore, to make each shaft large enough to cross both tunnels of a pair. Each shaft was a steel caisson; the two on the Manhattan side were about 300 feet from the river, and were sunk without compressed air. The Long Island City shafts were on the river side of the bulkheads, and compressed air was used; after sinking to full depth a strong concrete floor was put in below the tunnel level and the roof of the caisson removed. The shields for the work under the river were then built inside the shafts, the caisson roof with suitable airlocks replaced above the tunnel level, compressed air put on, and the shields started on their way. On the Manhattan side the shields were also built in the shafts and then pushed eastward, in tunnel excavation previously made, the cast-iron tunnel lining being built as the shields were moved forward, and the space between the tubes and the rock thoroughly filled with riprap and cement grout. After moving about 100 feet, nearly to the place where the shields would break out of rock, airlock bulkheads were built between the shields and the shafts and compressed air put on. Quicksand was met almost immediately after breaking out of rock, and the most serious difficulties of the work were at once encountered, with methods unperfected and working force untrained.

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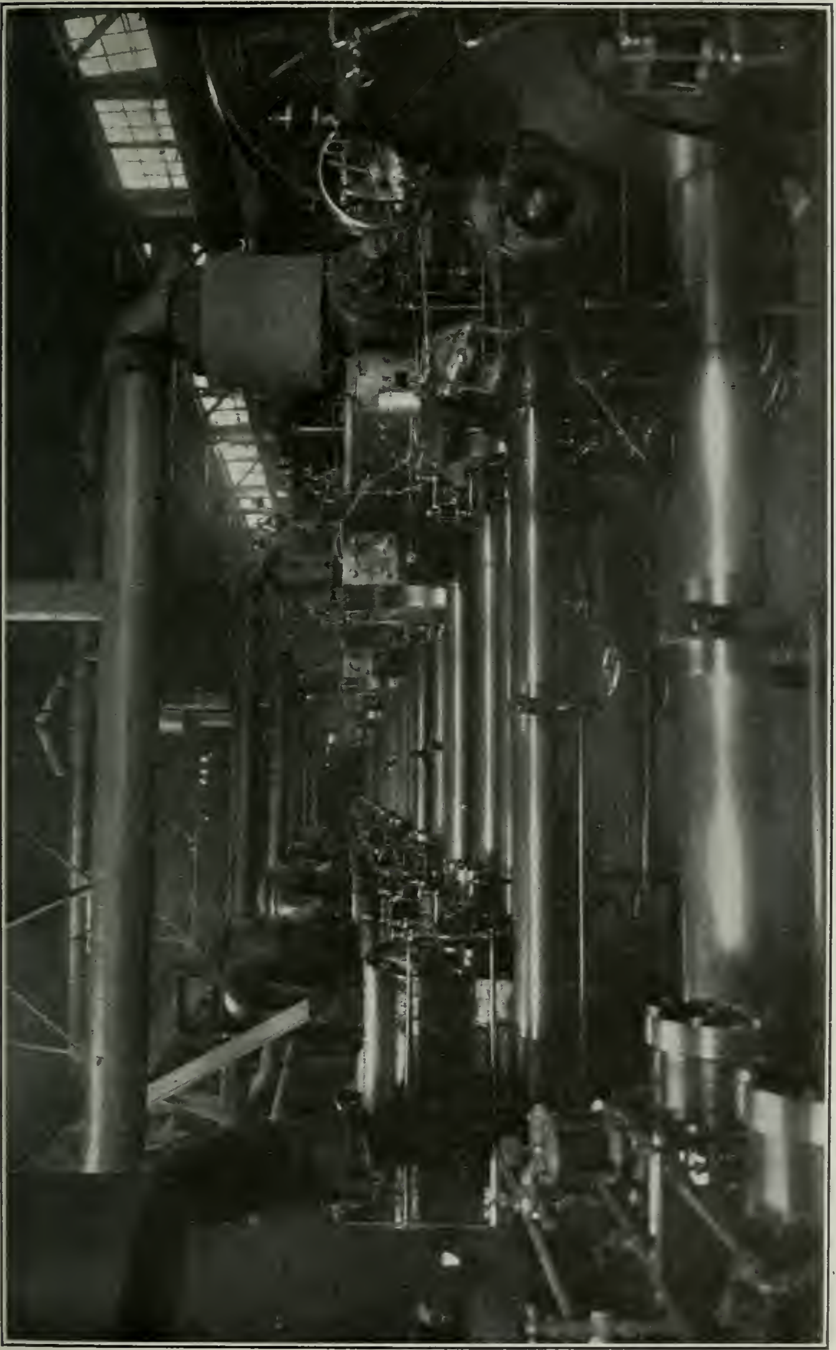
[5] For details of dimensions and weight of cast-iron tunnel lining see table on page 384.

One of the difficulties anticipated and encountered was the escape of large quantities of air from the face of the heading, and two precautions were taken: one consisted of covering the bed of the river over the tunnel with a thick bed of clay to hinder the escape of air through it, and this proved very helpful. The amount thus used was more than 300,000 cubic yards, most of it obtained from a place 35 miles distant. After the tunnels were built this clay had to be removed and dumped at sea, a distance of about 24 miles. This was a large item of cost, but there is no doubt that it was wisely incurred. The other precaution taken was to provide a very extensive plant for compressing air to be sent into the tunnels. At the beginning of the work the plant provided on each side of the river to supply four headings had a capacity of 25,000 cubic feet per minute of free air—that

Plate 23.



Pennsylvania Railroad. Manhattan air compressors for East River tunnels.

is to say, measured at normal pressure. The first tunnels to emerge from rock into the quicksand were three on the Manhattan side, and it was quickly found that the plant intended for prosecuting the work simultaneously in four tunnels was barely sufficient for two. The Manhattan plant was enlarged as soon as possible to a capacity of 35,000 cubic feet per minute; the plant on the opposite side of the river was enlarged still more, and finally had a capacity of 45,000 cubic feet of free air per minute. It may be mentioned that the cost of plant of all kinds for the construction of these tunnels was about $2,500,000.

It would be tedious if I were to follow the various methods of working tried and abandoned; the discouragement when it became clear that unless better methods could be devised disaster could hardly be avoided; but we will pass at once to the methods finally developed by which, in the hands of a trained force, success was finally attained.

The successful method in quicksand is illustrated on Plate 24. The right hand portion of the plate represents the stage of the work when the shove of a shield has just been completed; the erection of a ring is being commenced; excavation must be resumed in the face, the breasting planks advanced and strutted, and the condition obtained which is shown in the left-hand side of the view, where the preparation is complete for another shove. It will be readily understood that if the quicksand is fully saturated it will be impossible to advance the planking, because any void excavated will be filled immediately by the liquid quicksand; therefore, the condition of the quicksand must be changed so that it will not flow, or, in other words, it must be dried out. This is effected by maintaining the air pressure slightly greater than that required to balance the hydrostatic head, which results in driving the water back from the face, drying it sufficiently to permit removing the top plank, or the top but one, excavating, and replacing it in the advanced position desired; this gives access behind the next plank, where excavation is made and the plank placed in the new, advanced position, and so on until the entire face has been advanced, with only a small portion open at any time.

It will be noticed that but little more than half the face is shown in the figure as protected, and the question will arise whether the air pressure could be raised sufficiently to dry and

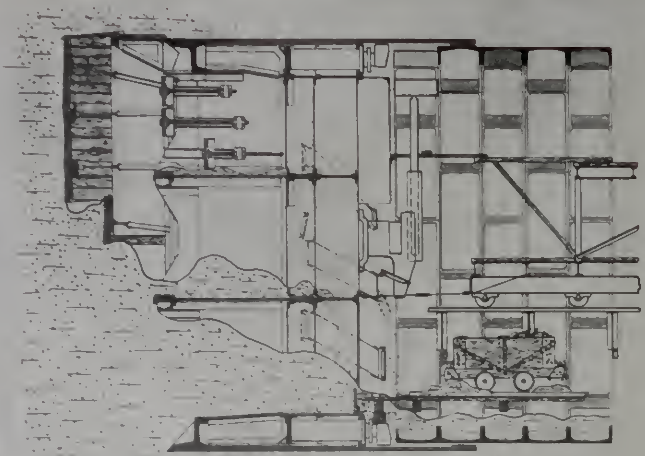


Fig. 1
Preparing for Shove

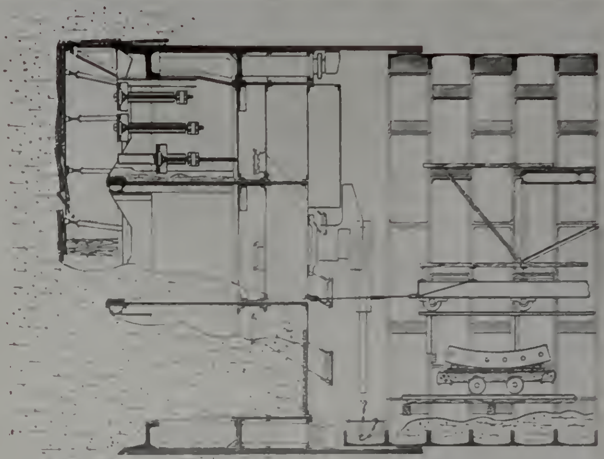


Fig. 2
After Shove Erecting Iron.

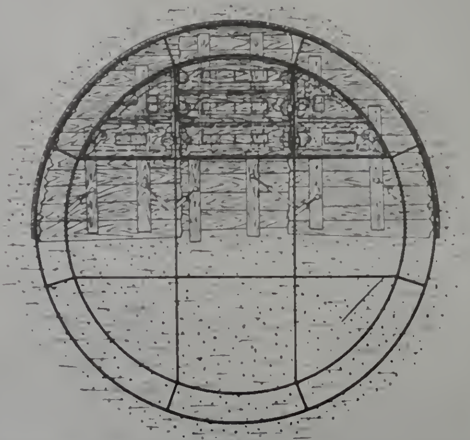


Fig. 3.
Section.- Shutters & Breasting.

Pennsylvania Railroad, East River tunnels. Method of tunnelling in quicksand.

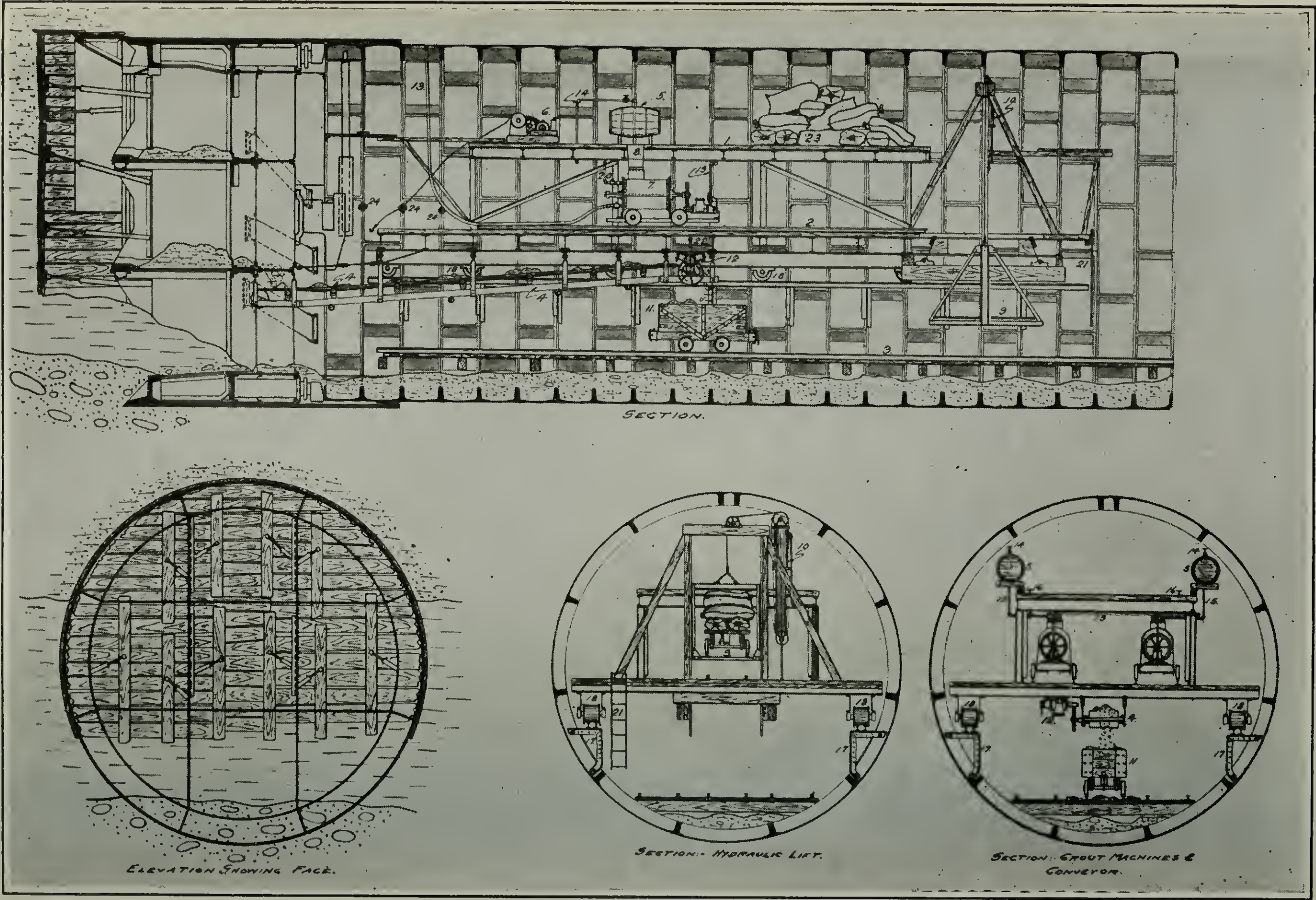
plank the heading to the very bottom. In quicksand this was not necessary, for it was found practicable to shove the shield forward when in the condition shown in the left-hand figure—the operation being to apply the pressure to the jacks and shovel the sand back from the bottom pockets as vigorously as possible; the facility thus given for more material to enter the bottom pockets tends to relieve the resistance at the cutting edge. It was found extremely dangerous to raise the pressure sufficiently to dry the sand at the bottom of the excavation, as will be briefly explained. Of course, the air pressure in the tunnel is practically the same everywhere at any given moment, but in a tunnel 23 feet in diameter the water pressure in the face is about 10 pounds per square inch greater at the bottom than at the top; therefore, if the air pressure were raised sufficiently to dry the materials at the bottom, the excess pressure at the top would be ten pounds per square inch. Under such a pressure the escape of air through the joints of the facing plank would become very great; the sand would soon be carried away in considerable quantity; an opening would be forced through the overlying earth; the escape of air would be then greatly increased, and some portion of the planking, deprived of the earth backing, would collapse, and the air would rush out in large volume, forming what is known as a "blow."

Usually, in the East River tunnels, the air balanced the water near the tunnel axis, varying with the nature of the material and the skill and judgment of the tunnel boss. With firmer material than quicksand, the planking was carried farther down, as shown in Plate 25, the material in the central portion containing more clay, holding air better, and flowing less readily, with gravel in the bottom giving greater resistance to the forward movement of the shield.

Even when skill had been acquired and care was exercised the escape of air would sometimes get beyond control. I have no doubt that as much as 40,000 to 50,000 cubic feet per minute was blown out during short periods from a single heading. The escape has been as much as 25,000 cubic feet per minute for 24 hours or more. The most effective way to stop a blow was to dump quickly a large amount of clay from a dump scow.

Many blows were checked in their incipient stage in the tunnel by throwing bundles of hay or sacks or balls of clay into

PLATE 25.



Pennsylvania Railroad, East River tunnels. Method of tunnelling in sand, clay, and gravel.

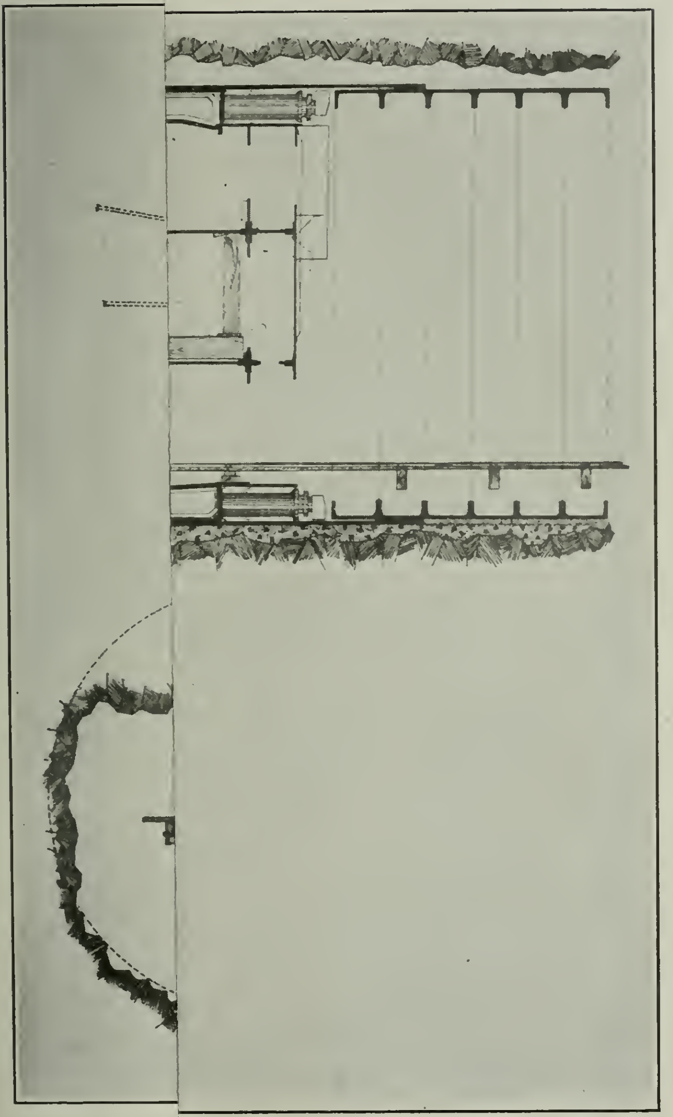
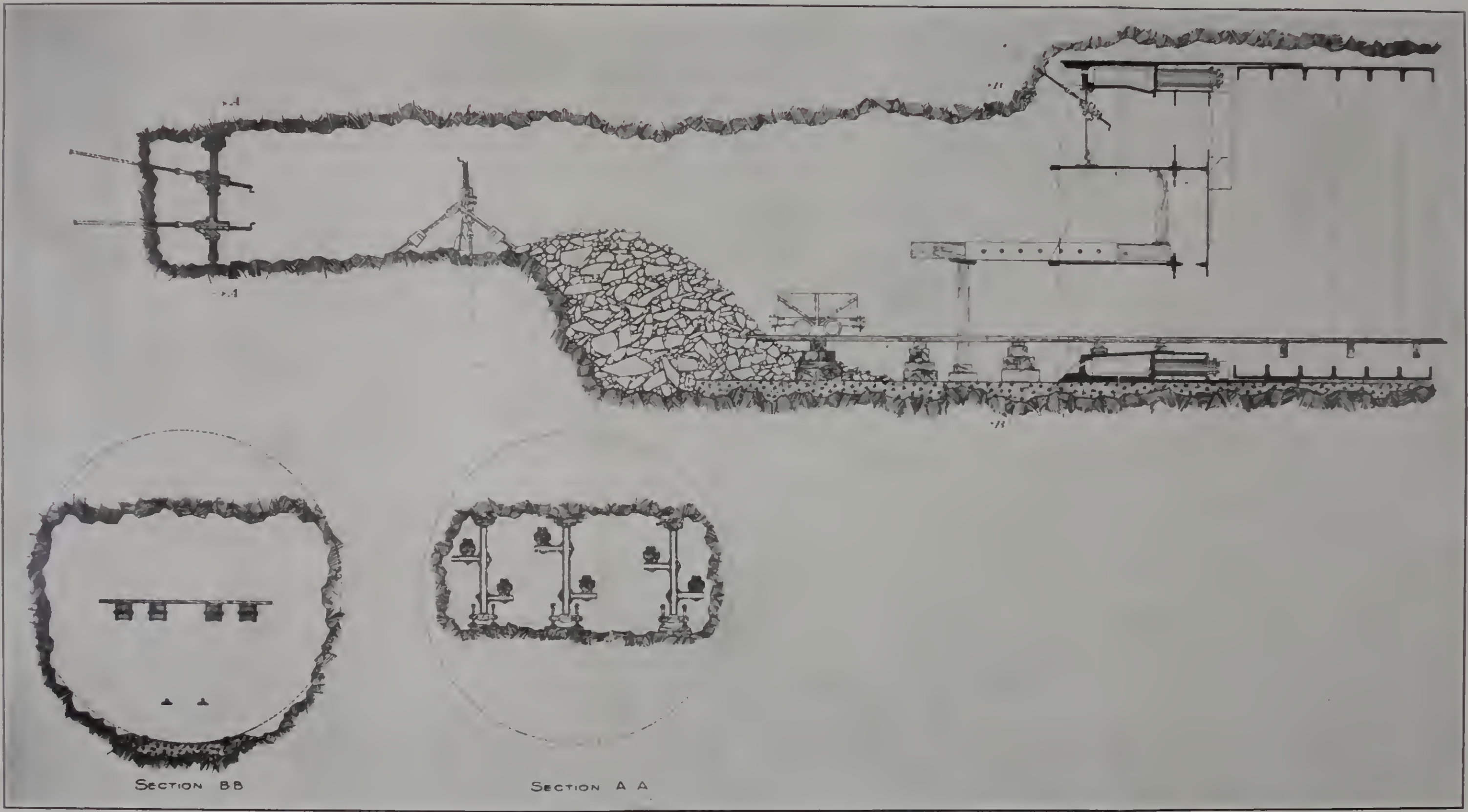


PLATE 26.



Pennsylvania Railroad, East River tunnels. Method of tunnelling in rock.

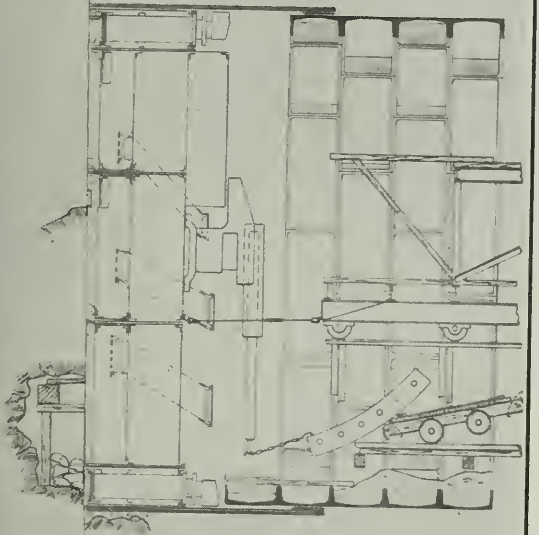
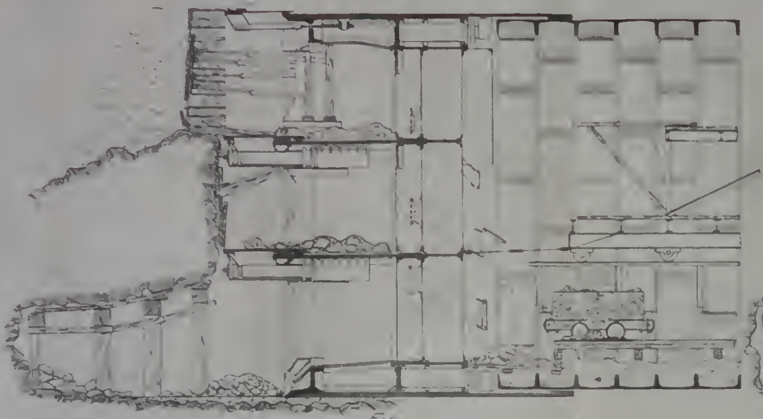
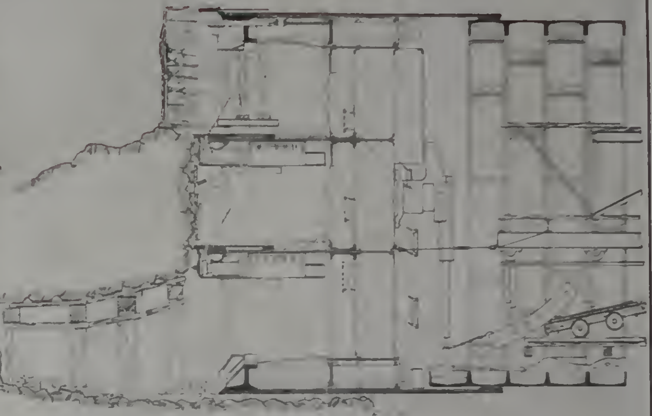


FIG 2
ter Shore Erecting
1



FIG



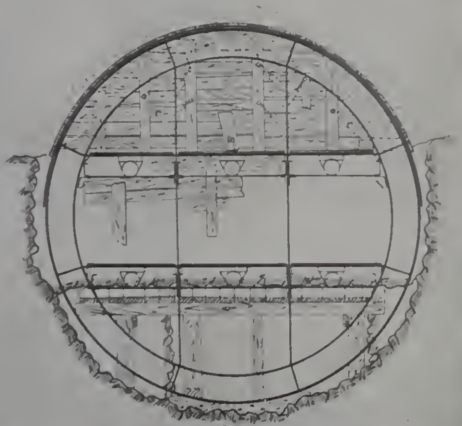
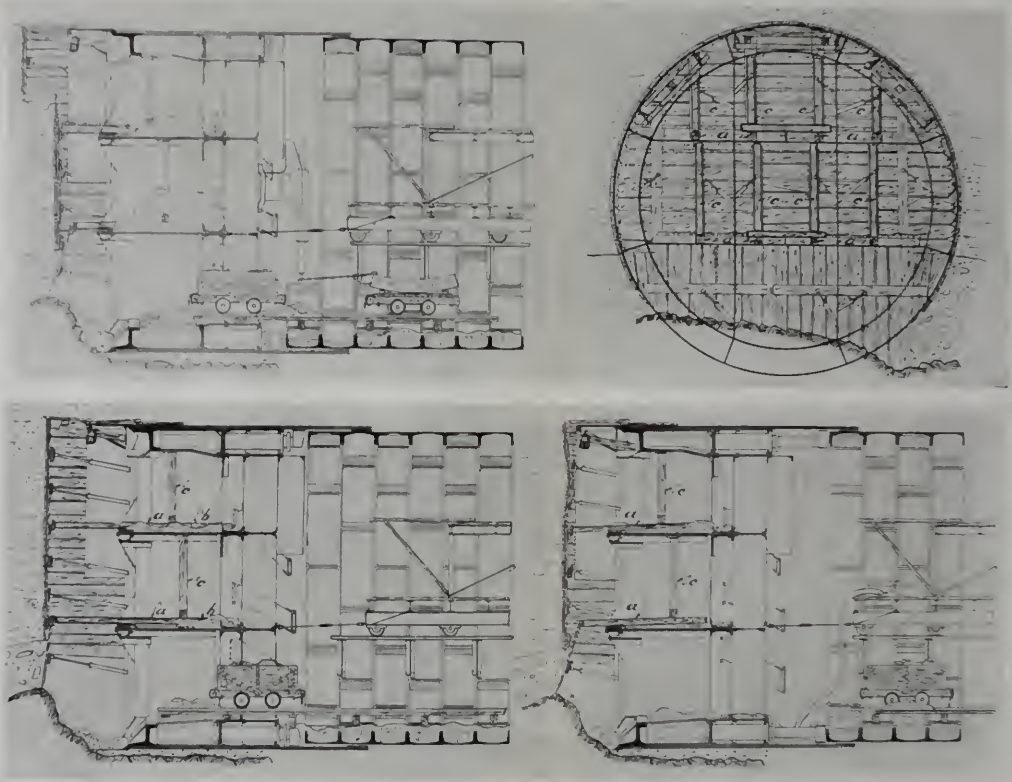


FIG 3

Pennsylvania Railroad East River tunnels. Method of tunnelling free rock and earth. Bottom heading.



Pennsylvania Railroad, East River tunnels. Method of tunnelling, rock in bottom.

the opening being formed. This involved much danger to the men attempting it; if the attempt failed and a great outrush of air occurred the men were liable to be drawn into it and disappear in the river bed. Several such cases have occurred in recent years; only one man has escaped after being drawn into the opening.

A very severe blow, one wrecking the face protection, would be followed by an inrush of water and earth, and not only the men in front of the shield but those in the tunnel would be in danger.

It will doubtless be realized from this description that success depended on experience acquired on that work. In the early period progress averaged less than a foot a day for many weeks. In the first tunnel the shield settled a foot below the desired grade in moving a distance of 25 feet; many tunnel castings were broken; the risks constantly met were appalling; a large loss to the contractors seemed impending, and the railroad company's entire terminal project seemed at stake. The sensible course was taken by suspending work in this tunnel, giving the quicksand time to settle together and become compacted, and transferring the working force to other tunnels where the difficulties were somewhat less. Methods were studied and improved from day to day, and when work was resumed in the troublesome tunnel no great trials were encountered. The daily programme increased steadily, and finally became an average of 10 feet per day, month after month, and the contractors made a handsome profit.

When rock was encountered, percussion air drills were used. Where the excavation was all rock the method finally adopted was to drive a large centre heading 30 feet or more in advance (Plate 26). The bench was also taken out well in advance of the shield. A light track was laid through the shield for the muck cars, and the greater part of excavation was thus kept at some distance from the shields. The drilling for enlargement to full size was done with drills mounted in the forward part of the shield. With these arrangements the average daily programme became about 3 feet.

Where the surface of the rock was a little below the top of the tunnel the heading was smaller and usually became a bottom heading, and in poor rock could not be kept far in advance of the shield (Plate 27). Where the rock was not high enough to permit driving a heading the rock was all excavated immediately in front of the shield (Plate 28), and the progress was the slowest under this condition. Whenever the rock surface was below the top of the tunnel some form of timbering the earth face above the rock was necessary.

As the shields approached each other from opposite sides of the river some anxiety in regard to the accurate meeting of the two headings was unavoidable.

PLATE 29.

Pennsylvania Railroad, East River tunnels. View in completed tunnel.

As a precautionary measure, the relative positions of the approaching shields were ascertained while they were some 50 or 60 feet apart by pushing a large pipe from the face of one heading to the other, through which line and levels were checked, and accurate meetings of the shields assured. In the four East River tunnels the discrepancies in alignment and levels varied from ⅛ inch to ⅜ inch, with an average of ¼ inch.

The placing of the concrete lining followed next. The view (Plate 29) shows a tunnel lined with concrete and ready for track. The trough-like form of section was devised by Mr. A. J. Cassatt, late president of the Pennsylvania Railroad. The width of the trough is about one foot greater than that of the widest Pullman car now in use, and the benches are a few inches below the level of the car windows. It is believed that in case of derailment the train will come to a stop without a shock and passengers may reach the benches readily from the platforms or the windows.

LEAKAGE IN PENNSYLVANIA RAILROAD RIVER TUNNELS.

The cast-iron lining is an effective waterproofing, and, while not absolutely water-tight, the leakage is insignificant. A sump of some form is provided at the lowest point of each tunnel or pair of tunnels and pumped out when necessary by pumps regularly installed. The daily leakage into the 5½ miles of river tunnels of the Pennsylvania Railroad is 2300 gallons. The magnitude of this may be better appreciated by stating that it amounts to one drop per lineal foot of tunnel every 17 seconds, or by stating that the entire amount of leakage for one day would be removed in one or two minutes by a pump of the capacity ordinarily used by contractors for foundations. The pumps provided at the new dry docks at the Brooklyn Navy Yard would remove the day's leakage in about two seconds.

OPERATION.

The tunnels eastward from the station were put in operation for the use of the Long Island Railroad, September 8, 1910; the entire system came into use November 27, 1910, and has continued in service without interruption of any kind.

VENTILATION OF RIVER TUNNELS.

While doubt was entertained as to its necessity, mechanical ventilation was provided for all the tunnels except the Hudson River tunnel, largely as a measure of insurance; if not provided and found required after the tunnels were put in use the resulting loss in traffic might not be recovered for a long time. Experience has shown that the movement of trains, forcing the air ahead, causes an entire change of air in the Pennsylvania Railroad tunnels within a short time, and the fans provided for ventilation are not used. They may prove useful, however, in the possible occurrence of fire in the tunnel, to remove smoke and facilitate the escape of passengers. Such an occurrence, by reason of the extraordinary precautions taken, is an extremely remote contingency. In the Hudson and Manhattan Railroad tunnels, where the distances between shafts are greater, the fans are used occasionally.

TABLE OF DIMENSIONS AND WEIGHTS OF CAST-IRON TUNNEL LININGS.

Tunnel.	Outside diameter of tube.	Width of ring.	Minimum thickness of metal.	Width of flanges.	Weight per lin. ft. of tunnel, lbs.	
Hudson & Manhattan:						
Uptown:						
Moir's section (1889).......	19′ 6″	20″	1¼″	9″	8,280	
New sec. (1902):						
North tube....	19′ 5¼″	20¼″	1½″	8″	7,565	
South tube....	16′ 7″	24″	1 7/16″	8″	5,670	Standard.
South tube....	16′ 7″	18″	1 7/16″	8″	6,340	Heavy.
Downtown.......	16′ 7″	24″	1 7/16″	8″	5,670	Standard.
South tube......	16′ 7″	18″	1 7/16″	8″	6,340	Heavy.
N. Y. City Subway.	16′ 8″	22″	1⅛″	7″	3,992	In rock and above water in earth.
Manhattan to Brooklyn........	16′ 8½″	22″	1⅛″	7½″	4,545	Standard.
	16′ 8½″	22″	1⅛″	7½″	5,133	In Brooklyn slip.
	16′ 8½″	22″	2″	7½″	5,593	Under bulkhead.
Belmont...........	16′ 10″	26″	1⅛″	8″	4,615	
Pennsylvania R. R.:						
North River Div...	23′ 0″	30″	1½″	11″	9,609	Standard.
North River Div...	23′ 0″	30″	2″	11″	12,127	Heavy.
East River Division.	23′ 0″	30″	1″	8″	5,166	Under land; full rock section.
East River Division.	23′ 0″	30″	1¼″	9″	6,776	Under land; surface of rock between top and centre of tunnel.
East River Division.	23′ 0″	30″	1½″	11″	9,102	Standard.

Spectrographic Study of Tellurium. WM. L. DUDLEY and E. V. JONES. (*J. Am. Chem. Soc.*, xxxiv, 995.)—Tellurium, well purified, was converted into the tetra-chloride, and fractionally precipitated by hydrazine hydrochloride. The spectrographs of 20 fractions showed no variations, except that in the last fractions copper lines appeared. On this basis the theory of a higher homologue as an impurity is rejected, and the authors are led to account for the anomaly of the atomic weight of tellurium by the assumption that it is "a mixture of nearly equal parts of substances differing but little in atomic weight and remarkably similar in other properties."

RECENT DEVELOPMENTS IN STEAM TURBINES.*

BY

H. T. HERR,

Vice-President and General Manager, The Westinghouse Machine Company.

APPENDIX I.

THERMODYNAMICS.

I. The first law of thermodynamics is the law of the conservation of energy,—heat being a form of energy.

First Principle.—When a body does work, it loses an amount of energy equal to the work done, because its energy is its capacity for performing work.

Second Principle.—When work is done on a body it gains an amount of energy equal to the work done, because the body which does the work loses that amount.

Third Principle.—When heat is supplied to or abstracted from a body, it gains or loses that amount of energy, because heat is a form of energy.

To place these principles in the form of an expression and to deduce the first thermodynamic equation:

Let W'' = work done by a body.
Let W' = work done on a body.
Let Q'' = heat supplied to a body.
Let Q' = heat abstracted from a body.

Then the gain of energy of the body = $Q'' + W'$,
and the loss of energy of the body = $Q' + W''$.
Subtracting the loss of energy from the gain of energy gives:

Effective gain of energy = $Q'' + W' - Q' - W''$.
Let E'' = the final energy of a body.
Let E' = the initial energy of a body.

Then the effective energy = $E'' - E'$.
From the above:

$$E'' - E' = -(W'' - W') + (Q'' - Q') \qquad \text{(1)}$$

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*Continued from page 327

If W represents the effective work, and Q represents the effective heat supplied, we have from (1)

$$E'' - E' = - W + Q,$$

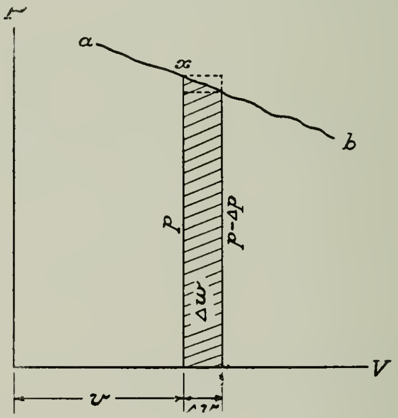
which is the first equation of thermodynamics.

II. The second law of thermodynamics states that it is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature.

In consequence of the second law, no heat engine converts, or can convert, more than a small fraction of the heat supplied to it into work, a large part being necessarily rejected as heat.

The ratio $\frac{\text{heat converted into work}}{\text{heat taken in by the engine}}$ is always a fraction much less than unity. This fraction is called the thermodynamic efficiency.

Fig. A.



In every heat engine there is a working substance, which alternately takes in and rejects heat. In general, it suffers changes of volume and does work by overcoming resistance to these changes. The working substance may be gaseous, liquid, or solid. In almost all actual heat engines, however, the working substance is a fluid. In some it is air, in some a mixture of several gases. In the steam engine the working fluid is steam or a mixture (in varying proportions) of water and steam.

With a fluid for working substance, work is done by changes of volume only, and its amount depends solely on the relation of pressure to volume during the change, and not at all on the form of the vessels in which it takes place.

III. The general expression for the work done by a fluid in expanding may be deduced as follows:

As has been stated, the work done is some function of the volume, or $W = f(v)$.

Let Fig. A represent a pressure volume diagram on which pressures are plotted as ordinates and volumes as abscissæ.

Suppose a fluid expands from initial pressure and volume at point a, tracing any line such as ab. At any point such as x, let the pressure be represented by p and the volume by v.

At any point on the curve ab, closely adjacent to x, the pressure would be $p - \Delta p$ and the volume $v + \Delta v$.

Let ΔW represent the area under the curve ab between the ordinates p and $p - \Delta p$.

From the figure:

Area ΔW is less than area $p\,(\Delta v)$.
Area ΔW is greater than area $(p - \Delta p)\,(\Delta v)$.

Divide these inequalities by Δv:

$$\frac{\Delta W}{\Delta v} < p$$

$$\frac{\Delta W}{\Delta v} > p - \Delta p$$

If Δv approaches zero as a limit, the derivative of W with respect to v is not greater than p, or

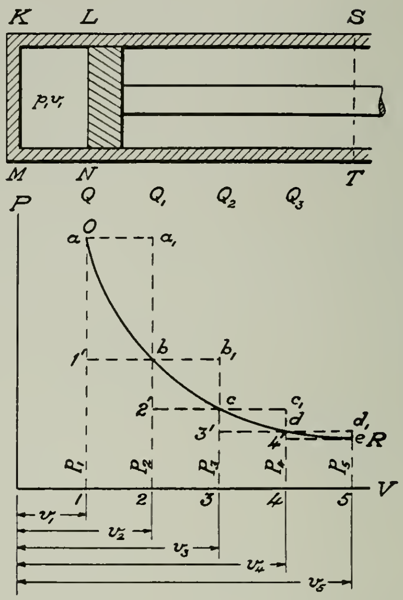
$$\frac{dW}{dv} \ngtr p, \text{ also,}$$

$$\frac{dW}{dv} \nless p.$$

Therefore since $\frac{dW}{dv}$ is neither greater nor less than p, $\frac{dW}{dv} = p$, which is the general expression for the work done by a fluid in expanding.

IV. To prove that the work done by a fluid in expanding is represented by the area under the curve as plotted on the pressure volume diagram:

Fig. B.



Let Fig. B represent a cylinder and piston, and let the dotted line *ST* be the position of the piston *NP* at the end of the stroke. Let *KLMN* be a body of gas at p pressure and v volume.

On the pressure volume diagram, let the point *O* represent the pressure and volume of the gas in the cylinder at any instant; then, as the gas expands by the movement of the piston to the end of the stroke, it will trace the line *OR*.

Then the line *OR* will represent the action of the gas during expansion.

Let A = area of piston LN.
Let $S = MN$.
Let ΔS = small movement of piston, such as from Q to Q_1, Q_1 to Q_2, etc.
Let p_a = the average pressure from the first to the second position of the piston; then

$$p_2 < p_a < p_1.$$

Multiplying this inequality by $(v_2 \rightarrow v_1)$

$$p_2\,(v_2 - v_1) < p_a\,(v_2 - v_1) < (p_1\,(v_2 - v_1).$$

Since the average force on the piston is the area times the pressure:

Average force = $(p_a A)$, and the work done $(\triangle W_1)$ in the first movement of the piston is:

$$\triangle W_1 = p_a A \triangle S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Also, $$v_1 = AS$$

$$v_2 = A\ (S + \triangle S)$$

Subtracting $$v_2 - v_1 = A \triangle S$$

Substituting in (1) $$\triangle W_1 = p_a\ (v_2 - v_1)$$

From Fig. B:

$$\begin{array}{l} \text{Area } 11'\,b2 < \triangle W_1 < 1aa'\,2 \\ \text{Area } 22'\,c3 < \triangle W_2 < 2bb'\,3 \\ \text{Area } 33'\,d4 < \triangle W_3 < 3\,cc'\,4 \\ \text{Area } 44'\,e5 < \triangle W_4 < 4dd'\,5 \\ \hline \end{array}$$

Adding these inequalities:

$$\text{Area } 11'\,b2'\,c3'\,\,d4'\,e5 < W < 1\,aa'\,bb'\,cc'\,dd'\,5$$

By taking the division indefinitely small, it is apparent that W = area under the curve.

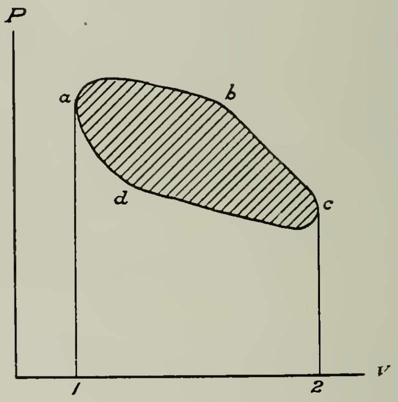
V. *Cyclic Process.*—When a body goes through a series of states and returns to its original state, it is said to perform a cyclic process.

The first equation of thermodynamics is given in I: $E'' - E' = -W + Q$. For a cyclic process, since the body returns to its inital state, $E'' = E'$. Therefore $-W + Q = 0$. Hence $Q = W$, or in a cyclic process the work a body does is equal to the heat supplied.

Generally, in heat engines, the working substance returns periodically to the same state of temperature, pressure, volume, and physical condition. Each time this has occurred the substance is said to have passed through a complete cycle of operations. For example, in a condensing steam engine, water taken from the hotwell is pumped into the boiler; it then passes into the turbine or cylinder as steam, passes thence into the condenser, and again as water into the hotwell, and completes the cycle by returning to the same condition as at first obtained.

In the theory of heat engines it is of first importance to consider as a whole the cycle of operations performed by the working substance. If each cycle is not completed, matters are complicated by the fact that the substance is in a state different from its initial state, and may therefore have changed its stock of internal energy. After the cycle is completed, however, the internal energy of the substance is necessarily the same as at first, since the condition is in every respect the same. Hence, in a cyclic process, the following equation must hold good: Heat taken in = work done + heat rejected. In approaching the theory of heat engines, it is convenient, in the first instance, to consider the action of an engine in which the working substance is any one of the so-called permanent gases, or a mixture of them, such as air. The word "permanent," as applied to a gas, is to be understood only as meaning that the gas is liquefied with difficulty by the use of extremely low temperature and high pressure.

Fig. C.



So long as gases are under conditions of pressure and temperature widely different from those which produce liquefaction, they conform very approximately to certain simple laws which may be regarded as rigorously applicable to ideal substances called perfect gases.

These laws are very nearly, though not absolutely, true for air, oxygen, nitrogen, hydrogen, and carbonic oxide, except when these are at specially high pressures or low temperatures. Hydrogen probably comes nearest to the ideal of a perfect gas.

A cyclic process is represented on a pressure volume diagram by a closed curve, such as in Fig. C, and the work done is represented by the area enclosed by such curve. This may be readily understood by taking the point a as the initial and final state of a fluid after passing through the cyclic process represented in Fig. C, and from consideration of the first and second laws of thermodynamics.

Thus:

W'' = area $abc21$ = work done by the body.
W' = area $adc21$ = work done on the body.
Therefore W = area $abcd$.

VI. Perfect gases have been found to comply with the four following laws, commonly called after their discoverers:

Law 1 (Boyle).—The volume of a given mass of gas varies inversely as the pressure, provided the temperature be kept constant. Thus if v be the volume of a given quantity of any gas and p the pressure, then so long as the temperature is unchanged v varies inversely as p, or $pv =$ constant.

Law 2 (Charles).—Under constant pressure equal volumes of different gases increase equally for the same increment of temperature; also, if the gas be heated under constant pressure, equal increments of its volume correspond very nearly to equal intervals of temperature as determined by the scale of a mercury thermometer.

Experiments show that the amount by which a gas expands when its temperature is changed by one degree Fahrenheit (its pressure being kept constant) is about 1/493 of its volume at 32° F. Thus if 493 cubic inches of air, or any other permanent gas at a temperature of 32° F., is heated to 33° F., its pressure remaining constant, its volume alters to 494 cubic inches; similarly, if the gas be cooled from 32° F. to 31° F., its volume changes from the original 493 cubic inches to 492, and so on. Finally, therefore, its volume would become 0 at —461° F. if the same law could be held to apply at indefinitely low pressures. Any actual gas would change its physical state before so low a temperature were reached.

The above may be concisely expressed by saying that if temperature be reckoned not from the ordinary zero, but from a point 461° below the zero of Fahrenheit's scale, the volume of a given quantity of gas, kept at constant pressure, is proportional to the temperature reckoned from that zero. Temperatures so reckoned are called absolute temperatures, and the point −461° F. is called absolute zero temperature. Denoting any temperature according to the ordinary scale by t and the corresponding absolute temperature by T, we have $T = t + 461$ on the Fahrenheit scale and $T = t + 274$ on the Centigrade scale.

Law 3 (Regnault).—The specific heat at constant pressure is constant for any gas. By specific heat at constant pressure is meant the heat taken in by one pound of substance when its temperature rises one degree Fahrenheit, while the pressure remains unchanged, the volume being allowed to change. The law states that this quantity is the same for any one gas, no matter what its temperature, or what the constant pressure, at which the process of heating takes place. Another important quantity in the theory of heat engines is the specific heat at constant volume,—that is, heat taken in by one pound of a substance when its temperature rises one degree Fahrenheit, while the volume remains unchanged—the pressure being free to change.

An obvious difference between the heating of a gas at constant pressure and at constant volume is that when heated at constant volume the gas does no work, whereas heating at constant pressure involves the expansion of the gas, and consequently the performance of an amount of work equal to the product of the pressure and the increase of volume.

Law 4 (Joule).—When a gas expands without doing external work and without taking in or giving out heat, and therefore without changing its stock of internal energy. its temperature does not change. This fact was established by the experiments of Joule. He connected a vessel containing compressed gas, by means of a pipe with a closed stopcock, with another vessel which was empty. Both vessels were immersed in a tank of water and were allowed to assume a uniform temperature. Then the stopcock was opened and the gas distributed itself between the two vessels, expanding without doing external work. After this the temperature of the water in the tank was found to have undergone no change. The temperature of the gas was unaltered and no heat had been taken in or given out by it and no work had been done by it. Since the gas had neither gained nor lost heat and had done no work, its internal energy was the same at the end as at the beginning of the experiment. The pressure and volume had changed, but the temperature had not. The conclusion follows that the internal energy of a given quantity of gas depends on its temperature and not upon its pressure or volume. In other words, a change of pressure and volume not associated with a change of temperature does not alter the internal energy.

From the first law of thermodynamics, $E'' - E' = - W'' + W' + Q$. From Joule's experiment, therefore, $W'' = 0$, as there was nothing to do work on $W' = 0$, as the gas was not compressed; $Q = 0$, as the temperature of the water in the tank was not changed. Therefore $E'' - E' = 0$, or $E'' = E'$; also, $T'' = T'$; hence, if the energy of a body remains constant, the temperature remains constant, and *vice versa.*

VII. The numerical equation, expressed in Boyle's and Charles's laws, may be written $\left(\frac{pv}{m}\right)$ = a constant, when the temperature is constant, and $\left(\frac{v}{mT}\right)$ = a constant when the pressure is constant. In Boyle's law it is apparent that $\left(\frac{pv}{m}\right)$ is some function of T and in Charles's law $\left(\frac{v}{mT}\right)$ is some function of p, or, expressed numerically:

$$\frac{pv}{m} = f(T) \quad \ldots\ldots\ldots\ldots(1) \quad \text{(Boyle's Law).}$$

$$\frac{v}{mT} = f'(p) \quad \ldots\ldots\ldots\ldots(2) \quad \text{(Charles's Law).}$$

From (1), $$\frac{v}{m} = \frac{f(T)}{p} \ldots\ldots\ldots\ldots(3)$$

From (2), $$\frac{v}{m} = Tf'(p) \ldots\ldots\ldots\ldots(4)$$

Equating (3) and (4):

$$\frac{f(T)}{p} = Tf'(p), \text{ or}$$

$$\frac{f(T)}{T} = pf'(p) \ldots\ldots\ldots\ldots(5)$$

Now $\frac{f(T)}{T}$ is either a constant or a variable. We know we can vary T without varying p; therefore, the right-hand member of 5 is constant; the left-hand member of 5 is assumed variable, but that is impossible; therefore $\frac{f(T)}{T}$ is a constant. Therefore, $fT = CT$.

Substituting this value in equation (1) $pv = mCT$. By experiments for air $C = 53.2$, provided p is in pounds per square foot and v in cubic feet, m in pounds and T in degrees absolute.

VIII. Deduction of the equation for the change of internal energy of a perfect gas: On the pressure volume diagram, Fig. D, let line ab represent the process through which a perfect gas of mass m changes its state from energy E', temperature T', pressure p', volume v' to energy E'', temperature T'', pressure p'', volume v''; also let the line ac represent the process of expansion of the gas at constant pressure, from energy E', temperature T', to energy E''', temperature T'', volume v'''.

From the first equation of thermodynamics:

$$E''' - E' = - W_p + Q_p \quad \text{(at constant pressure)} \ldots . (1)$$

The work done, as has been shown, is represented by the area under the curve on the pv diagram; therefore,

$$W_p = p'(v' - v') = p'v''' - p'v';$$

also, by the combined law of Boyle and Charles:

$$p'v''' = mCT''$$
$$p'v' = mCT'$$

By substituting in the equation for W_p

$$W_p = mCT'' - mCT' = mC\,(T'' - T')$$

Let K_p = the specific heat at constant pressure; then by (VI) Regnault's law $Q_p = mK_p\,(T'' - T')$.

Substituting the values W_p and Q_p in equation (1):

$$E''' - E' = - mC(T'' - T') + mK_p(T'' - T') = m(K_p - C)(T'' - T').$$

Let $(K_p - C)$ = a constant = K.

But by Joule's law, $E''' = E''$, since the points b and c in Fig. D have the same temperature T''.

$$E'' - E' = mK(T'' - T'), \text{ or}$$
$$K_v = K_p - C.$$

IX. Proof that the specific heat at constant volume is constant: On the pressure volume diagram (Fig. E), let one pound of gas expand at constant volume from point a to point b. Let the inital energy and temperature be represented by E', T' and the final energy and temperature by E'', T'', and let $T'' = T' + 1$.

FIG. D.

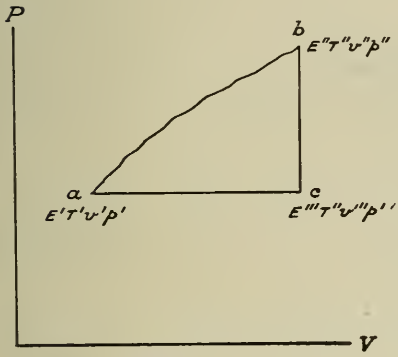
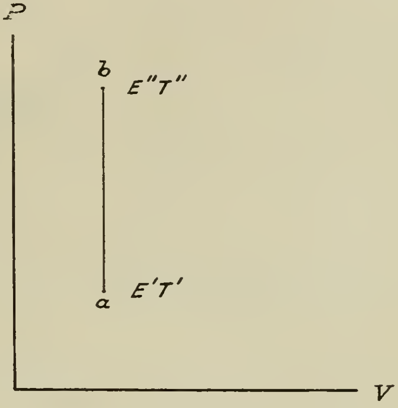


FIG. E.



Let K_v = the specific heat at constant volume; then since one pound of gas has been taken and raised one degree Fahr., $Q_v = K_v\ (T'' - T')$. $W_v = 0$, since there is no area under the curve.

Substituting in the first equation of thermodynamics:

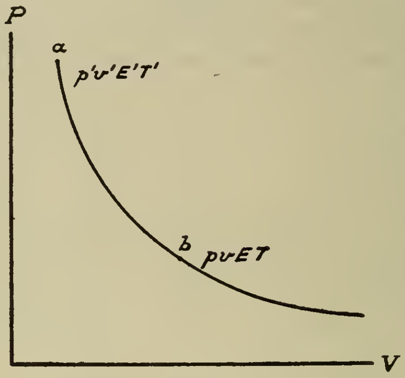
$$E'' - E' = K_v (T'' - T') = K_v; \text{ but}$$
$$K_v = K_p - C, \text{ but } K_p \text{ and } C \text{ are constants; therefore } K_v \text{ is a constant}$$

X. Adiabatic expansion: When a gas expands or is compressed, without having heat supplied to it, or abstracted from it by external agencies, it is said to expand or compress adiabatically. To prove that pv^γ = constant:

$$\gamma = \frac{\text{Specific heat at constant pressure } (K_p)}{\text{Specific heat at constant volume } (K_v)}$$

On the pressure volume diagram (Fig. F) let m pounds of a perfect gas expand from point a to point b adiabatically, and let point a have an initial pressure, volume, energy, and temperature p', v', E', T', and let point b be any point on the curve with pressure, volume, temperature, and energy p, v, E, T. To deduce the equation of the curve ab between the two points.

FIG. F.



By the first equation $E - E' = -W + Q$, but by definition $Q = 0$; therefore $E - E' = -W$; also

$$E - E' = mK_v(T - T') = -W.$$

In this equation T and W are variables. Taking the derivative with respect to v,

$$mK_v\frac{dT}{dv} = -\frac{dW}{dv} = -p \ldots\ldots\ldots\ldots\ldots\ldots (1) \quad \text{(See III.)}$$

From the combined law of Boyle and Charles $pv = mCT$. Taking the derivative in this equation with respect to v:

$$\frac{d}{dv}(pv = mCT) = p + v\frac{dp}{dv} = mC\frac{dT}{dv}$$

Rearranging, $\frac{dT}{dv} = \frac{1}{mC}\left(p + v\frac{dp}{dv}\right)$.

Substituting this value of $\frac{dT}{dv}$ in equation (1):

$\frac{K_v}{C}\left(p + v\frac{dp}{dv}\right) = -p$. From paragraph VIII, $C = K_p - K_v$.

Substituting this value of c in the above equation:

$$K_v p + K_v v \frac{dp}{dv} = -K_p p + K_v p.$$

Cancelling the common term $K_v p$ and dividing the equation by pvK_v:

$$\frac{1}{p} \cdot \frac{dp}{dv} + \frac{K_p}{K_v} \cdot \frac{1}{v} = 0$$

Therefore $$\frac{d}{dv}(\log_e p) + \frac{d}{dv}\left(\frac{K_p}{K_v} \log_e v\right) = 0$$

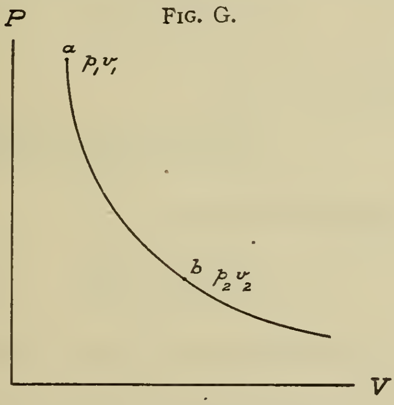
Substituting (γ) for $\left(\frac{K_p}{K_v}\right)$ in this equation and rearranging:

$$\frac{d}{dv}(\log_e p + \gamma \log_e v) = 0$$

Therefore $\log_e p + (\gamma) \log_e v =$ constant,
Therefore $\log_e (pv^\gamma) =$ constant.
But if the $(\log_e)$ of a quantity is equal to a constant, the quantity itself is equal to a constant.

Therefore $pv^\gamma =$ constant. $\left\{\text{For air } (\gamma) = \frac{K_p}{K_v} = 1.41\right\}$

FIG. G.



XI. All the common cases of expansion and compression follow the law $pv^n = constant$.

For isothermal expansion or compression, the exponent $n = 1$. For expansion or compression at constant pressure, the exponent $n = 0$, and for expansion or compression at constant volume $n =$ infinity.

To find the expression for the work done by a fluid when it expands according to the law $pv^n = constant$, the following solution is given:

On the pressure volume diagram (Fig. G) the curve ab represents the expansion of a gas of mass m according to the equation $pv^n = constant$. Let point a have a pressure and volume p_1v_1 and point b a pressure and volume p_2v_2, and let any other point on the curve ab have a pressure and volume pv. From paragraph III, $\frac{dW}{dv} = p$. Also from the equation of the curve $pv^n = p_1v_1^n = p_2v_2^n$, therefore, $p = p_1v_1^n \cdot v^{-n}$.

Substituting the value of p given above:

$$\frac{dW}{dv} = p_1v_1^n \cdot v^{-n} = \frac{d}{dv}\left(\frac{p_1v_1^n}{1-n} \cdot v^{1-n}\right)$$

Transposing, $$\frac{d}{dv}\left(W - \frac{p_1v_1^n}{1-n} \cdot v^{1-n}\right) = 0$$

Therefore $$\left(W - \frac{p_1v_1^n}{1-n} \cdot v^{1-n}\right) = \text{constant} \ldots\ldots\ldots\ldots\ldots (1)$$

When $v = v_1$, $W = 0$, as no expansion has taken place.

Substituting in (1) $0 - \frac{p_1v_1}{1-n} = \text{constant} = K$.

Substituting value of K in (1)

$$W = \frac{p_1v_1^n v^{1-n} - p_1v_1}{1-n} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Substituting in equation (2) v_2 for v,

$$W = \frac{p_1v_1^n v_2^{1-n} - p_1v_1}{1-n}$$

Substituting in above equation $(p_2v_2^n)$ for its equal $(p_1v_1^n)$,

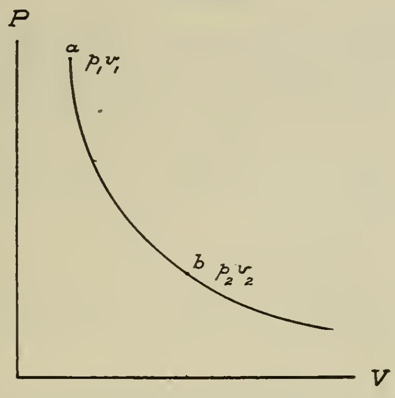
$$W = \frac{p_2v_2 - p_1v_1}{1-n} \text{ or } \frac{p_1v_1 - p_2v_2}{n-1}$$

Therefore $$W = \frac{p_1v_1 - p_2v_2}{n-1} = \frac{mC(T_1 - T_2)}{n-1}$$

It is evident that the above formula fails when $n = 1$, when is the case of isothermal expansion or compression.

XII. To find the work done and heat supplied when a perfect gas expands isothermally: The isothermal expansion of a gas follows Boyle's law,—that is, the pressure and volume remain constant when the temperature is constant, or during the expansion there is no change in temperature. Let the curve *ab* on the pressure volume diagram (Fig. H) represent isothermal expansion of a gas of mass *m* from pressure and volume p_1v_1 at *a* to pressure and volume p_2v_2 at *b*.

FIG. H.



$$p_1v_1 = p_2v_2 = pv$$

Therefore $$p = p_1v_1\frac{1}{v}.$$

From III, substituting the value of p,

$$\frac{dW}{dv} = p_1v_1\frac{1}{v} = \frac{d}{dv}(p_1v_1 \log_e v)$$

Transposing, $$\frac{d}{dv}(W - p_1v_1 \log_e v) = 0$$

Therefore $$W - p_1v_1 \log_e v = \text{constant} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Let $v = v_1$, then $W = 0$

Substituting in equation (1) $p_1v_1 \log_e v_1$ for the constant which it equals and transposing,

$$W = p_1v_1(\log_e v - \log_e v_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Let $v = v_2$ and substitute in equation (2)

$$W = p_1v_1 \log_e \frac{v_2}{v_1} \text{ or}$$

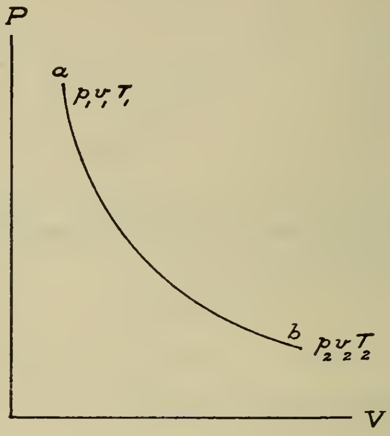
$$W = \frac{p_1v_1}{\cdot 434} \log_{10} \frac{v_2}{v_1}$$

Therefore $$W_T = \frac{p_1v_1}{\cdot 434} \log_{10} \frac{v_2}{v_1} = \frac{mCT'}{\cdot 434} \log_{10} \frac{v_2}{v_1}$$

From the first equation of thermodynamics $E'' - E' = W_T + Q_T$. Since, in isothermal expansion, the temperature remains constant, by Joule's law $E'' = E'$ or $E'' - E' = 0$; therefore $Q_T = W_T$, or the heat supplied is equal to the work done in isothermal expansion.

XIII. Deduction of the relation between the initial and final temperatures and the initial and final volumes of a perfect gas expanding adiabatically: Let the curve *ab* on the pressure volume diagram (Fig. I) represent the adiabatic expansion of a gas of mass m, from point a, at pressure p_1, volume v_1, temperature T_1 to point b at pressure p_2, volume v_2, and temperature T_2. From the equation for adiabatic expansion:

FIG. I.



$$p_1 v_1^{\gamma} = p_2 v_2^{\gamma},$$

and from the combined law of Boyle and Charles,

$$p_1 v_1 = mCT_1 \text{ or } p_1 = \frac{mCT_1}{v_1};$$

similarly,

$$p_2 = \frac{mCT_2}{v_2}$$

Substituting the values of p_1 and p_2 in the first expression above,

$$mCT_1 v_1^{\gamma - 1} = mCT_2 v_2^{\gamma - 1} \text{ or } \frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{\gamma - 1}$$

which is the relation, in adiabatic expansion, between the temperatures and volumes.

XIV. Deduction of the corresponding relation between pressures and temperatures:

$$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$$

Extracting the $(\gamma)^{\text{th}}$ root

$$p_1^{\frac{1}{\gamma}} \; v_1 = p_2^{\frac{1}{\gamma}} \; v_2$$

From the combined law of Boyle and Charles,

$$v_1 = \frac{mCT_1}{p_1} \text{ and } v_2 = \frac{mCT_2}{p_2}$$

Substituting the values of v_1 and v_2 in the 2nd equation,

$$p_1^{\frac{1}{\gamma}-1} \; mCT_1 = p_2^{\frac{1}{\gamma}-1} \; mCT_2$$

Transposing, $$\frac{T_1}{T_2} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}-1} = \left(\frac{p_2}{p_1}\right)^{\frac{1-\gamma}{\gamma}}$$

which is the relation between the initial and final temperatures and initial and final pressures when a gas expands adiabatically.

SUMMARY.

In the above deductions, the first equation of thermodynamics,—*i.e.*, $E'' - E' = -W + Q$,—holds good for all substances.

The following equations hold for perfect gases:

$$pv = mCT$$
$$E'' = E' = mK\,(T'' - T').$$
$$pv^{n} = \textit{constant}.$$

In the last equation, for different values of n, the following common expansions obtain:

When $n = 1$ . . . . Isothermal,
When $n = 0$ . . . . Constant pressure,
When $n = a$ . . . . Constant volume.
When $n = \gamma$ . . . . Adiabatic.

The expression for the work done has two equations, *i.e.*, when n is not equal to 1, and when n is equal to 1.

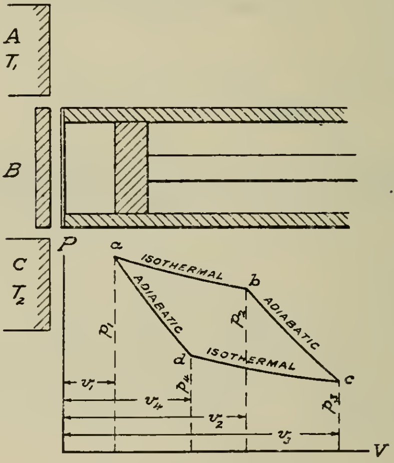
$$W_{n\pm 1} = \frac{p_1v_1 - p_2v_2}{n - 1} = \frac{mC(T_1 - T_2)}{n - 1}$$

$$W_{n=1} = \frac{p_1v_1}{\cdot 434} \log_{10} \frac{v_2}{v_1} = \frac{mCT_1}{\cdot 434} \log_{10} \frac{v_2}{v_1}$$

The values of the constants in the above equations—provided p is in pounds per square foot, v in cubic feet, m in pounds, and T in degrees absolute—are:

C = 53.2.
K_v = 131.6 foot-pounds.
K_p = 184.8 foot-pounds.
γ = 1.41.

FIG. J.



XV. *Carnot's Cycle.*—Carnot considered an ideal engine in which the working substance was a perfect gas which was caused to pass through a cycle of changes, each of which is either isothermal or adiabatic. A cylinder and piston is imagined composed of perfect non-conducting materials, except the head of the cylinder, which is a perfect conductor of heat. In the diagram (Fig. J), *A* is an indefinite source of heat at constant temperature T_1, *B* is a perfect non-conducting cylinder head, and

C an indefinite source of heat at constant temperature T_2. T_2 is less than the temperature of the source of heat T_1. It is supposed that A, B, or C can be applied at will to the end of the cylinder.

Suppose the cylinder to contain one pound of a perfect gas at temperature T_1, volume v_1 and pressure p_1.

(1) Apply A and allow the piston to move outward slowly through any convenient distance. The gas expands isothermally at T_1 temperature, and takes in heat from the hot body A, and does work.

The pressure changes to p_3 and the volume to v_2.

(2) Remove A and apply B, allowing the piston to go on moving outward. The gas then expands adiabatically, doing work at the expense of its internal energy, and the temperature falls to T_2. The pressure is then p_2 and the volume v_3.

(3) Remove B and apply C, forcing the piston inward slowly. The gas is compressed isothermally at T_2 temperature, since the smallest increase of temperature above T_2 causes the heat to pass into C. Work is done on the gas and heat is rejected to the cold body C. Let this be continued until a certain point is reached by the piston such that the fourth operation will complete the cycle.

(4) At such point, remove C and apply B. Continue the operation, which is now adiabatic. The pressure and temperature will rise, and if the point at which B is applied has been properly chosen, when the pressure is restored to its original value p_1, the temperature will also have risen to its original value T_1. In other words, the third operation must be stopped when a point is reached such that an adiabatic line drawn through this point will pass through the initial point. This completes the cycle. From the diagram:

$$\left(\frac{v_4}{v_1}\right)^{\gamma-1} = \frac{T_1}{T_2}; \text{ also} \left(\frac{v_3}{v_2}\right)^{\gamma-1} = \frac{T_1}{T_2}.$$

Equating, $$\left(\frac{v_3}{v_2}\right)^{\gamma-1} = \left(\frac{v_4}{v_1}\right)^{\gamma-1}$$

Therefore $$\frac{v_3}{v_2} = \frac{v_4}{v_1} = R$$

In other words, the ratio of isothermal expansion equals the ratio of isothermal compression. Let this ratio be denoted by R.

XVI. The efficiency of Carnot's cycle may be deduced in the following manner: From the diagram (Fig. J), and from the preceding paragraph:

Since this is a cyclic process, the first equation of thermodynamics becomes $E'' - E' = 0$, therefore $W = Q$ or $W = Q'' - Q'$. The efficiency is equal to the work done divided by the heat supplied; or,

$$\varepsilon = \frac{W}{Q''} = \frac{Q'' - Q'}{Q''} \text{ but,}$$

$$Q''_T = \frac{mCT_1}{\cdot 434} \log_{10} \frac{v_2}{v_1}$$

$$Q'_T = \frac{mCT_2}{\cdot 434} \log_{10} \frac{v_3}{v_4}$$

$$Q''_T = mCT_1 \log_e R \text{ and } Q'_T = mCT_2 \log_e R.$$

Substituting these values in equation for ε:

$$\varepsilon = \frac{mCT_1 \log_e R - mCT_2 \log_e R}{mCT_1 \log_e R}$$

Cancelling like terms $\varepsilon = \dfrac{T_1 - T_2}{T_1}$

XVII. *Carnot's Cycle Reversed.*—With the aid of Fig. J, assume that an imaginary engine is to act so that the same indicator diagram as traced in the description of Carnot's cycle is reproduced, but in the direction opposite to that followed in XV. Starting as before from the point p_1v_1 in Fig. J, and with the gas at temperature T_1, the following operations will obtain:

(1) Apply *B* and allow the piston to move outward. The gas expands adiabatically, tracing the curve on the diagram until the temperature becomes T_2, at the point whose pressure and volume is p_4v_4.

(2) Remove *B* and apply *C*. Allow the piston to move outward, expanding the gas isothermally at T_2 temperature, taking heat from *C*, and tracing the curve to p_3v_3.

(3) Remove *C* and apply *B*, compressing the gas adiabatically until the temperature has risen from T_2 to T_1, which will be at the point whose pressure and volume is p_2v_2.

(4) Remove *B* and apply *A*, continuing the operation isothermally at T_1 temperature. Heat is, in this last operation, re-

jected to A and the cycle is completed by the curve to the point whose pressure and volume is p_1v_1.

In this process the engine is not doing work. On the contrary, a quantity of work is spent upon it equal to the area of the diagram, or $mC\,(T_1 - T_2)\log_e R$, and this work is converted into heat. Heat is taken in from C in the first operation to the amount $mCT_2\log_e R$. Heat is rejected to A in the fourth operation to the amount $mCT_1\log_e R$. In the first and third operations there is no transfer of heat.

The action is in every respect the reverse of that which occurred in XV. The same work is spent upon the engine as was formerly done by it. The same amount of heat is now given to the hot body A as was formerly taken from it. The same amount of heat is now taken from the cold body C as was formerly given to it. The reversal of the work has been accompanied by an exact reversal of each of the transfers of heat.

An engine from which this is possible is called, from the thermodynamic standpoint, a reversible engine. In other words, a reversible heat engine is one which, if forced to trace out its indicator diagram, reversed in direction, so that the work which would be done by the engine, when running direct, is actually spent upon it, will reject to the source of heat the same quantity of heat as, when running direct, it would take in from the source, and will take from the receiver of heat the same quantity as, when running direct, it would reject to the receiver. By the source of heat is meant the hot body, which acts as the source of heat when the engine is running direct, and by the receiver is meant the cold body, which then acts as receiver.

XVIII. The idea of thermodynamic reversibility is of great interest, for the reason that no heat engine can be more efficient than a reversible engine, when both work between the same limits of temperature. This principle, established by Carnot, is deduced as follows from the laws of thermodynamics: Consider two engines, one reversible and the other non-reversible, and let them work by taking in heat from a hot body A, and by rejecting heat to a cold body C.

If it were possible for the non-reversible engine to be more efficient than the reversible, it would take in less heat from A and reject correspondingly less heat to C in doing each unit of work.

Suppose the non-reversible engine, working direct, be set to drive the reversible engine, as a reversed machine, so that the reversible engine converts work into heat.

With such a condition, for every unit of work done by the engine driving the reversible engine, a greater quantity of heat would be supplied to the source of heat *A* than was taken from it by the non-reversible engine in driving the reversible engine.

It was shown, however, in Carnot's cycle, that when the engine was operated reversed, the same amount of heat was transferred from the cold body to the hot body as was spent in driving the engine, or as would have been transferred from the hot body to the cold body if the Carnot engine operated direct; hence, with the assumption made above, the hot body would, on the whole, gain heat and the cold body lose an equal amount. Thus, the combined action of the two engines—one working direct and the other reversed—would result in a transfer of heat from the cold body *C* to the hot body *A*, which process might evidently go on without limit. The two engines, taken together, form a purely self-acting system, for the entire power generated in one engine is spent on the other and is sufficient to drive the other, and, assuming no mechanical friction, the double machine requires no help from external agencies. Hence the supposition that the non-reversible engine could be more efficient than the reversible engine has led to a result inconsistent with the second law of thermodynamics,—*i.e.,* that it is impossible for a self-acting machine, without the aid of some external agency, to transfer heat from a cold body to a hot body. The conclusion, therefore, is forced that no engine can be more efficient than a reversible engine, when both work between the same limits of temperature.

With the same reasoning, it will be apparent that if both engines are reversible, neither can be more efficient than the other, and hence all reversible heat engines taking in and rejecting heat at the same two temperatures are equally efficient; hence the expression which was obtained for the efficiency of Carnot's engine,—*i.e.,* $\frac{T_1 - T_2}{T_1}$ is the efficiency of any reversible heat engine taking in heat at T_1 temperature and rejecting it at T_2 temperature, and as no engine can be more efficient than one that is reversible, this expression is the measure of perfect thermodynamic efficiency. From this expression, therefore, no heat engine can convert into work a greater fraction of the heat which it receives than the difference of the absolute temperatures of reception and rejection of heat, divided by the absolute temperature of reception.

XIX. *Formation of Steam under Constant Pressure.*—The foregoing paragraphs have dealt with the thermodynamic laws with special reference to perfect gases. In the steam engine and steam turbine the working substance is water and water vapor, or steam, the physical properties of which are most conveniently stated by referring to what happens when steam is formed under constant pressure. This is substantially the process which occurs in the boiler of a steam engine when the engine is at work.

For convenience of illustration, assume a cylinder with a quantity of water, which take, say, as one pound, at temperature t_0, and let the piston press on the surface of the water with a force of P pounds per square foot. Let heat now be applied to the bottom of the cylinder. As heat enters the water it will produce the following effects:

(1) The temperature of the water rises until a certain temperature t is reached at which steam begins to be formed. The value of temperature t depends on a particular pressure P which the piston exerts. Until the temperature t is reached, there is nothing but water below the piston.

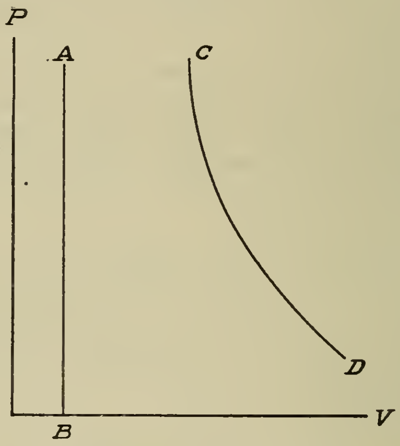
(2) As heat is added, steam is formed. The piston (which is supposed to exert a constant pressure) rises. No further increase of temperature occurs during this stage, which continues until all the water is converted into steam. During this stage the steam which is formed is said to be saturated. The volume which the piston encloses at the end of this stage,—*i.e.*, of one pound of saturated steam at pressure P and temperature t,—will be denoted by V in cubic feet.

(3) If, after all the water is converted into steam, more heat is allowed to enter the cylinder, the volume will increase and the temperature will rise. The steam is then said to be superheated.

XX. *Saturated and Superheated Steam.*—The difference between saturated and superheated steam may be expressed by saying that if water at the temperature of the steam be mixed with steam, some of the water will be evaporated if the steam is superheated, but none if the steam is saturated. Any vapor in contact with its liquid and in thermal equilibrium is necessarily saturated. When saturated, its properties differ considerably from those of a perfect gas, but when superheated, they approach those of a perfect gas more and more closely the further the process of superheating is carried on. Saturated steam at a given pressure can have but one temperature. Superheated steam at the same pressure can have any temperature higher than saturated steam at the given pressure.

XXI. *Sensible Heat.*—The amount of heat necessary to raise water from 32° F. to the boiling point (which is dependent on the pressure) is represented by h, and is called the sensible heat; therefore, $h = t - 32$.

FIG. K.



Latent Heat.—The amount of heat necessary to convert water into steam is called latent heat, and is represented by L. The total heat of steam is, therefore, the sum of the sensible and latent heat, or $h + L - H$.

Wet steam is a mixture of steam and water.

Saturated steam is steam which if compressed a little will partially turn into water.

Dry saturated steam is steam which contains no water.

The physical properties of water and steam may be represented on a pressure volume diagram, such as Fig. K, in which the point B represents the volume of a given amount of water

w. If this water is assumed to be in a cylinder and pressure is put on it, the line AB is traced, which since water is incompressible is parallel to the P axis. All points on the line CD represent dry saturated steam. All points between the lines AB and CD represent wet steam, and all points to the right of CD represent superheated steam. Steam follows very nearly the law

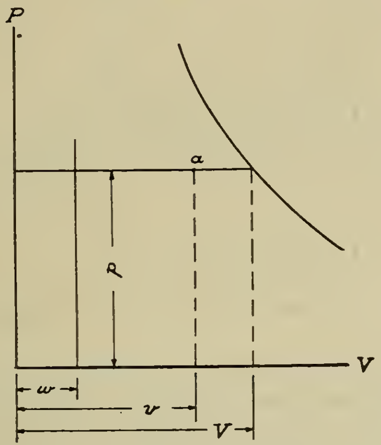
$$pv^{\frac{17}{16}} = \text{constant};$$

Superheated steam follows the law,

$$pv = mCT \text{ when } C \text{ is equal to } 85.5.$$

XXII. Expressions for latent heat L, total heat H, volume v, and energy of one pound of wet steam: Wet steam is said to have a dryness q when the amount of steam present is to the total amount as q is to 1, which may be represented by the fraction $\frac{\text{amount of steam present}}{\text{total amount}} = q$; q is therefore always less than 1, and it is evident that in one pound of wet steam of dryness q there are q pounds of steam and $1 - q$ pounds of water. The latent heat of wet steam is therefore qL, and the total heat of wet steam is $H = h + qL$; also, the volume of water in a mixture of one pound of wet steam is $w\ (1 - q)$. The volume of steam in the mixture of one pound of wet steam is equal to qV. The total volume is therefore $w\ (1 - q) + qV = v$.

FIG. L.



In Fig. L the point a represents the mixture of one pound of wet steam as referred to above. To determine the expression for the change of internal energy we assume as the starting point, in dealing with the heat required to produce steam, the state of water as being 32° F.

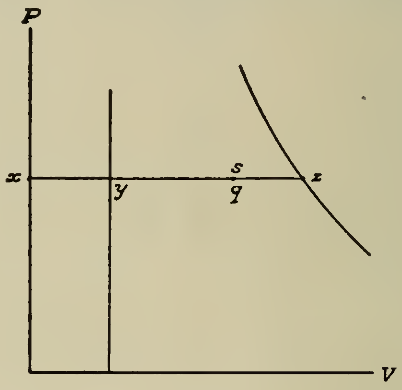
From the first law of thermodynamics, $E'' - E' = -W + Q$.

From the diagram Fig. L, $W = p(v - w)$, and $Q = (h + qL)J$, where J is the mechanical equivalent of heat = 778 foot-pounds. Let E_{32} equal the energy of water at 32° F.

Substituting, in the first equation, $E'' - E_{32} = -p(v - w) + J(h + qL)$, but $v = qV + (1 - q)w$, $v - w = qV + w - qw - w = q(V - w)$.

Substituting this value of $(V - w)$ in the above equation, $E'' - E_{32} = -pq(V - w) + J(h + qL)$.

FIG. M.



XXIII. On the pressure volume diagram Fig. M, let the line xz represent the conversion of water under constant pressure into steam, and let point s represent a certain quality of wet steam with dryness p. To show how the dryness of wet steam is represented on the pressure volume diagram,

$xy = w$ = volume of water present,
$xs = v$ = volume of water and steam at dryness (q),
$xz = V$ = volume of dry saturated steam, therefore,
$ys = v - w = qV + (1 - q)w - w = q(V - w)$.
$yz = V - w$,

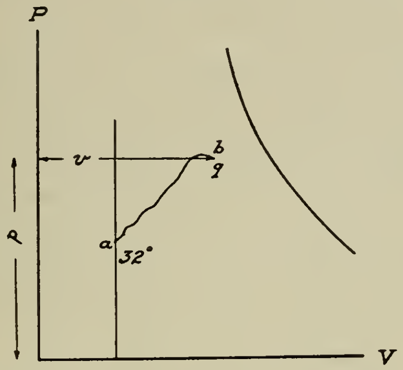
$$\frac{ys}{yz} = q\frac{(V - w)}{(V - w)} = q$$

$$\begin{aligned} sz &= yz - ys \\ &= (V - w) - q(V - w) \\ &= (V - w)(1 - q) \end{aligned}$$

$$\frac{ys}{sz} = \frac{q(V - w)}{(V - w)(1 - q)} = \frac{q}{1 - q}$$

XXIV. The expression for the heat required to form one pound of steam otherwise than at constant pressure may be deduced as follows: Let the curve *ab* on the pressure volume diagram Fig. N represent the expansion of one pound of water from 32° F. to wet steam at *b* with quality *q*. In the first equation of thermodynamics:

FIG. N.



$$E'' - E' = -W + Q; \text{ then,}$$
$$Q = E'' - E' + W,$$

From the diagram,

$E' = E_{32}$, therefore,
$E'' = E_{32} - pq(V - W) + J(h + qL).$
$W =$ area under the curve, therefore,
$Q = E_{32} - pq(V - W) + J(h + qL) - E_{32} +$ area under the curve, or
$Q = -pq(V - W) + J(h - qL) +$ area under the curve.

XXV. *Isothermal Lines for Steam.*—The expansion of volume which occurs during the conversion of water into steam under constant pressure is isothermal. It is obvious that steam, or any other saturated vapor can be expanded or compressed isothermally only when wet, and that evaporation (in the one case) and condensation (in the other) must accompany the process. On the pressure volume diagram isothermal lines for a working substance which consists of a liquid and contains vapor are lines of uniform pressure.

XXVI. *Adiabatic Lines for Steam.*—The form of adiabatic lines on the pressure volume diagram for the substances just described depends not only on the particular fluid but also on the proportion of liquid to vapor in the mixture. In the case of steam it has been shown that, if initially dry, it be allowed to expand adiabatically, it becomes wet, and if initially wet (unless very wet), it becomes wetter. When the mixture contains a very large proportion of water to begin with, adiabatic expansion tends to dry it by causing some of the water to evaporate under the reduced pressure which results from the expansion. To keep steam dry while it expands doing work, some heat must be supplied during the process of expansion. If the expansion is adiabatic so that no heat reaches the expanding fluid, a part of the steam is condensed, forming either minute particles of water suspended throughout the mass, or a dew upon the surface of the containing vessel. During expansion the temperature and pressure fall, and, as that part of the substance which remains uncondensed is saturated, the relation of pressure to temperature throughout expansion is that which holds in saturated steam.

(*To be continued.*)

Cements from Blast-furnace Slag. H. KÜHL. (*Tonind-Zeit.*, xxxvi, 1987.)—There are three classes of cement obtained from blast-furnace slag: (1) *Puzzuolana cements,* which consist of ground slag, containing 42 to 52 per cent. of calcium oxide, mixed with sufficient slaked lime to bring the content of calcium oxide up to 63 to 66 per cent. This cement is hardly superior to a good hydraulic lime, does not harden well in the air, and only feebly resists wear and tear. (2) *True Portland* and *iron-Portland cements*: in the former slag replaces clay in the mixture of raw materials used for making Portland cement clinker. Any slags may be used except such as contain excessive proportions of magnesium and manganese. Iron-Portland cement consists of a mixture of 70 per cent. Portland cement clinker and 30 per cent. of water-granulated blast-furnace slag. In strength and general properties iron-Portland cement is practically equal to Portland cement, but both have the disadvantage of being highly susceptible to chemical action, especially to the influence of sulphuric acid and magnesium salts. (3) *Blast furnace cements* are prepared by mixing rapidly-cooled and granulated slags, which possess innate hydraulic properties, with a considerable quantity of plaster of Paris. Such cements contain only a negligible quantity of free lime, and consequently offer great resistance to the action of acids and magnesium salts.

A BRIEF EXAMINATION OF THE ELECTRICAL PROPERTIES OF EGG-WHITE.[1]

BY E. F. NORTHRUP, Ph.D.

In connection with the subject of the production of electricity by animals, the writer became interested in making a brief examination of the electrical properties of albumen as found in the white of an egg. As the method employed in the test appears to be a good one for biologists to use in making similar tests, and as the results obtained were, to say the least, unexpected, the writer believes his experiment is worthy of record. As only one sample of egg-albumen was examined with care (though three other samples were superficially examined, and these exhibited similar properties), it is considered that the data are insufficient to establish " standard values." The method, however, of making the test is easy to apply and gives results without ambiguity.

A rough preliminary measurement was made to determine the electrical resistance of a fresh hen's egg between two copper wires inserted in the ends of the egg, each wire extending into the egg through its shell about 0.5 centimetre. It appeared at once that the fresh egg was the seat of a considerable electromotive force which would cause a galvanometer of moderate sensibility to deflect off its scale quite violently. By applying 24 volts to the electrodes in the ends of the egg for one minute and then joining these terminals to a millivoltmeter the instrument registered from 0.1 to 0.2 millivolt for the several minutes that it was observed. A fresh egg was selected to which *no* electric potential had been applied, and this also was found to be the seat of an electromotive force of the order of a millivolt. It was apparent that, if the resistance and other electrical properties of an egg (and, as appeared later, even the white of an egg when removed and placed in a container) were to be measured, some method similar to one of the methods used for determining the properties of a cell of battery must be employed. It was thereupon decided to set as the objects of the investigation, to measure (for a single sample) the specific resistance of egg-white, and to determine the residual electromotive force retained by a specimen of egg-white placed in a Kohlrausch cell, after the sample had been submitted for 600 seconds to 4 volts. It was further decided to trace the curves, called the potential difference curve, the polarization curve, the internal resistance curve, the current curve, and the recovery curve. These curves give the chief electrical characteristics of a battery and are suitable for giving similar information regarding the white of an egg and, presumably, of any sample of an organic fluid.

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[1] Communicated by the author.

FIG. 1.

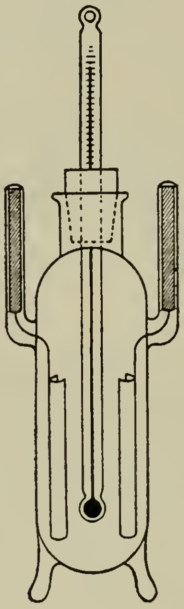
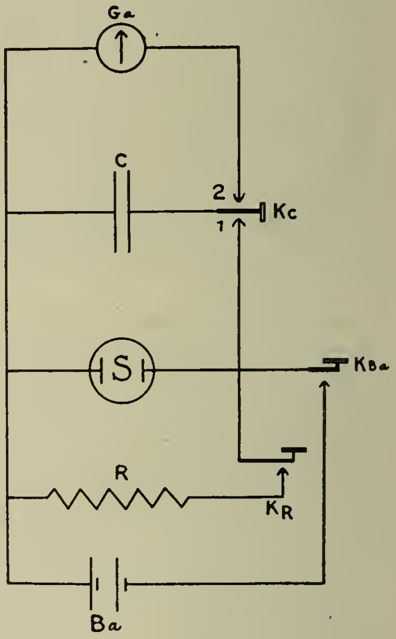


FIG. 2.



The precision of the measurements which follow is as good as the method permits of, because the observations were taken with care and all matters which could influence the precision received attention.

The albumen was taken from a perfectly fresh hen's egg and placed in a Kohlrausch cell of the form illustrated in Fig. 1. The cell had been previously washed out with acid, water, alcohol, and ether, and was quite clean and free from any water molecules. This cell was then placed in the system of electrical circuits shown in Fig. 2.

In these circuits, *Ga* is a D'Arsonval galvanometer used with a telescope and scale. Its deflections, when used as a ballistic instrument, were nearly proportional to the quantity of electricity discharged through its coil. *C* is a mica condenser of 1.5 microfarads capacity. *S* is the Kohlrausch cell containing the egg-albumen to be tested. *R* is a resistance. *Ba* is two cells of storage battery. This could be replaced with a Weston standard cell when it was required to determine the extent of the galvanometer deflection when the condenser *C* is charged to a known electromotive force and then discharged through the galvanometer. K_C is a key which in position 1 charges the condenser and when in position 2 discharges it through the galvanometer. K_{Ba} is a key which when closed submits the contents of the cell *S* to a potential difference of approximately 4 volts. K_R is a key which when closed joins the resistance *R* to the terminals of the cell *S*.

The procedure adopted was as follows: Before any electromotive force had been applied to the contents of *S*, K_C was joined to 1 and then to 2. The galvanometer deflected, indicating that the albumen in cell *S* had a potential. The albumen was then stirred with a glass rod and again tried for a potential. It was found to still have a potential, but a potential *the polarity of which could often be reversed* by stirring. Before stirring, the galvanometer deflected approximately 1.8 divisions toward the left-hand end of the scale, and, after stirring, approximately 2 divisions toward the right-hand end of the scale. As a previous determination of the value of a scale division in volts gave 1 scale division $=0.0096$ volt, the albumen was thus shown to be the seat of a potential which before stirring was $1.8 \times 0.0096 = 0.017$ volt in one direction, and after stirring $2 \times 0.0096 = 0.019$ volt in the opposite direction.

The key K_{Ba} was now closed, the other key being open, for exactly 600 seconds. This subjected the albumen to an applied potential of 4.13 volts for this number of seconds. Key K_R was then opened, and immediately thereafter the following program, to give data for the curves, was carried out: With K_{Ba} at all times open, and K_R open, K_C is joined to 1 and the condenser is charged with the potential possessed by the cell *S*. K_C is joined to 2 and the condenser discharged through the galvanometer. The deflection of this is noted. Then K_R is closed, and after an interval of 1 minute the condenser is again charged and discharged. K_R is now maintained closed for 68 minutes, except that at intervals of two minutes it is opened just long enough to charge and discharge the condenser by means of the key K_C. At these intervals the readings taken give the electromotive force of the cell upon open circuit. The condenser is also charged, K_R being closed, at intervals of two minutes which alternate with the open-circuit readings.

At the end of 68 minutes K_R was opened permanently and open-circuit readings were taken at brief intervals. In this way the data was obtained for plotting the curve of the recovery of the potential of the cell.

All the data obtained by the above procedure was carefully recorded. The values for the electromotive forces in volts, the current in ampères, the resistance in ohms, and the specific resistance are obtained from the relations:

$$E_x = \frac{dx}{ds} E_s \text{ ....} (1)$$

where E_s is the electromotive force of the standard cell used and d_s the corresponding deflection, and E_x is any other electromotive force corresponding to the deflection d_x.

$$X = \frac{E - E_1}{E_1} R \text{ ....} (2)$$

where E is the open circuit electromotive force, E_1 the fall of potential over the external resistance R, and X the resistance from terminal to terminal of the cell under test.

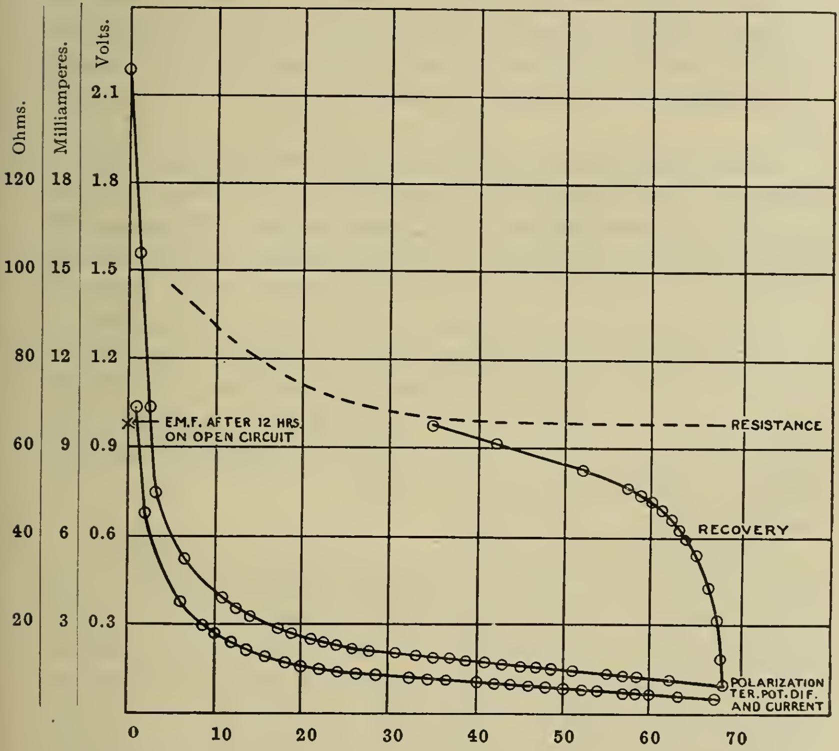
$$\gamma_t = \frac{R'_t}{R_t} \rho_t, \text{ ....} (3)$$

is an equation which gives the specific resistance γ_t (namely, resistance between opposite faces of a centimeter-cube) of the substance at a temperature of t degrees. To obtain the data for solving equation (3) the cell is filled with a saturated NaCl solution of known specific resistance ρ_t. R_t' is the measured resistance at temperature t of the cell filled with albumen, and R_t is that of the cell when filled with the saturated salt solution. The resistance of the cell in this latter case is measured by the well-known Kohlrausch method, in which a slide wire bridge, telephone detector, and current from a small induction coil are used.

The features of interest obtained in this test upon the electrical properties of egg-white are well set forth by the curves (Fig. 3) drawn from the data obtained by the measurements.

In obtaining the data and in drawing the curves the following constant values were used:

FIG. 3.



The resistance *R* (Fig. 2) was chosen 100 ohms.

The capacity *C* (Fig. 2) was chosen 1.5 microfarads.

The temperature of the contents of the cell at the time of the test was 22° C.

In reducing the resistivity of the albumen by using formula (3) the value ρ_t assigned to saturated NaCl solution at 22° C. was 4.24 ohms, and the measured resistance of the saturated NaCl solution in the cell was 9.66 ohms. The electromotive force of the standard Weston cadmium cell used in obtaining the value in volts of the galvanometer deflections was 1.0194 volts. A galvanometer deflection of 1 small scale division was equivalent to charging the condenser to a potential of 0.0096 volt.

The polarization curve shows that immediately after disconnecting the battery *Ba* (Fig. 2), which had applied for 10 minutes 4.13 volts to the cell, the cell retained an electromotive force of 2.2 volts. This electromotive force fell rapidly, because the cell was delivering current through 100 ohms external resistance. But at the end of one minute it still had an electromotive force of 1.56 volts and was delivering 10.5 milliampères. At the end of 68 minutes its electromotive force was about 0.1 volt.

It does not appear at all unexpected or unnatural that any substance, capable of being electrolyzed, should exhibit an electromotive force when placed in a cell with platinum electrodes after being subjected to a voltage. The gases which would form upon the surface of the two electrodes would, for a time, make the cell act in precisely the manner of an open-circuit battery. It is hard, however, to understand, even if albumen is an electrolyte, why the recovery of the electromotive force of the cell (as shown by the recovery curve) should be so rapid and reach 0.99 volt in 33 minutes. Nor would an inorganic electrolyte exhibit, as did the albumen, an electromotive force before it had been subjected to a potential.

The resistance curve, shown in dotted line, is deduced from the polarization and terminal potential difference curves. As the curve is obtained by dividing the difference of two very small quantities by a small quantity and then multiplying by 100, the precision obtained is very low. For this reason the resistance curve is given in dotted line and only suggests the order of magnitude of the resistance. Apparently the resistance of the albumen decreases somewhat with the time. By equation (3) the resistivity can be calculated. Thus

$$\gamma_t = \frac{\rho_t}{R_t} R'_t = \frac{4.24}{9.66} R'_t = 0.439 R'_t$$

If we call $R'_t = 70$ ohms at 30 minutes as a fair average value, we obtain $\gamma_{22} = 30.7$ as the resistivity for a centimeter-cube of the albumen at 22° C.

Probably a determination of resistivity by an alternating-current method would give a different and lower value, as a very rough test that was made seemed to indicate.

It was found by the writer that, if an egg is subjected to a very high potential, the albumen coagulates about the electrodes. This apparently greatly increases its resistance and very little current flows.

If an extended and more exhaustive investigation were to be made of the electrical properties of albumen, it would be desirable to fill the cell with a saturated salt solution and take data for a set of curves similar to those for albumen. The comparison of the curves in the two cases would bring out the peculiarities of the organic material.

The albumen molecules are altogether too complex to make it safe to suggest any hypotheses based upon this brief investigation as to the nature of the electric conduction of albumen, or to attempt to account for the presence of an electric potential in albumen which has not been previously subjected to an electromotive force.

The observations in the above investigation were made at the writer's request by Mr. H. H. Lester.

PALMER PHYSICAL LABORATORY,
Princeton, N. J.

Corrosion of Water Mains. R. KRZIZAN. (*Z. öffentl. Chem.*, xviii, 433.)—A portion of a cast-iron water main which had been in service for twenty years suddenly became defective. It had been asphalted inside and outside, but the corrosion went right through. A number of conical holes were scattered irregularly over the surface and were surrounded by graphite-like material containing particles of metallic iron. An analysis of the material showed the composition to be: metallic iron 5.98 per cent., ferric oxide and hydroxide 34.09, ferrous phosphate 9.63, ferrous silicate 37.16, ferrous sulphate 0.47, carbon 11.42, sulphur 0.097, manganese 1.362, copper 0.296 per cent. There was nothing in the water running through the pipe to account for this formation. The clay in which the pipe lay contained crystals of gypsum distributed irregularly in it. The corrosion is attributed to local currents set up by contact between the graphite particles and the iron in the presence of a solution of calcium sulphate at the points round the pipe where the crystals of gypsum were contained in the clay.

Fixation of Nitrogen by Alumina and Carbon. S. A. TUCKER and H. L. READ. (*Met. and Chem. Eng.*, x, 475.)—The interaction of pure alumina and commercial bauxite with carbon (petroleum coke) and pure nitrogen was investigated. The charge was heated in a graphite boat, in a graphite tube surrounded by a resistance mass of granular carbon. With pure alumina a product containing up to 30.19 per cent. of combined nitrogen was produced at 1800° C. to 2000° C.; below 1600° C. but little nitrogen was fixed, and above 2000° C. the aluminum nitride decomposed. The nitride, AlN, contains 34.06 per cent. of nitrogen. The presence of appreciable quantities of oxygen, sulphur dioxide, or hydrogen chloride in the nitrogen used is harmful. Producer gas would be a useful source of nitrogen, as the residual gas after the reaction could be burned and used to pre-heat the charge. Some impurities in the charge appear to act favorably, especially iron and lime. It is probable that the first stage of the reaction is the reduction of the alumina by the carbon, and that the nascent aluminum in the presence of fairly pure nitrogen combines with nitrogen preferably than with carbon. The impurities probably act as catalysts in the combination of nitrogen with aluminum. Aluminum nitride, on treatment with boiling water, slowly evolves ammonia, and would probably behave similarly in the soil. By boiling the nitride with alkali solution ammonia would be obtained quantitatively and the residual pure alumina would be available for use or as a marketable by-product. From these experiments there would be no difficulty in manufacturing aluminum nitride containing 30 per cent. nitrogen, as compared with the 17 to 20 per cent. of nitrogen in crude calcium cyanamide (nitrolim).

Neon as a Product of Radioactive Change. W. RAMSAY. (*Chem. Soc. Journ.*, ci, 1367.)—From previous experiments it was concluded that neon is produced when niton, *i.e.*, RaEm, is in contact with water. In this paper further evidence is adduced. The gases evolved from the springs at Bath are shown by analysis to contain 188 times as much neon per litre as ordinary air. This neon is assumed to be produced by the action of niton, as the gases also contain an abnormal amount of this emanation. The experimental evidence is this: 0.103 cubic millimetre of niton was sealed off in contact with a solution of thorium nitrate in about 5 cubic centimetres of water, and allowed to remain for two years. Then the gases were pumped off, and showed the spectra of helium and neon, in the proportion of 0.31 cubic millimetre of helium and about 0.17 cubic millimetre of neon. It was shown by investigation that the neon was not derived from any air which might be presumed to have leaked into the apparatus. Hence neon is produced when niton decomposes in the presence of water. Possibly it is a disintegration product of the niton, consisting of the union of five atoms of helium, or possibly the water is the cause of the reaction.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE PRECISION MEASUREMENT OF THE UNIT OF ELECTRIC CURRENT.

The completion of the extended research upon the silver voltameter at the National Bureau of Standards makes it desirable and timely to present a brief abstract of the work thus far prepared for publication. The experimental was done by the authors, Messrs. E. B. Rosa, G. W. Vinal, and A. S. McDaniel, of that Bureau.

THE SILVER VOLTAMETER.

PART I.

The first to make accurate measurements of electric current by electrochemical decomposition was Michael Faraday, who gave the name "volta-electrometer" to the apparatus which comprised his gas voltameter. Poggendorff, in 1847, made use of the silver voltameter, and since his time about sixty papers dealing with this instrument have appeared. The most important of the recent papers have dealt with the researches of the various national standardizing laboratories. It is necessary that the conditions under which the instrument may be used with precision be well understood, since the Electrical Congress, of London, in 1908, adopted the ohm and the ampère as the two primary electrical units, and the "international ampère" is defined in terms of the amount of silver deposited in the voltameter.

The present investigation at the Bureau of Standards began in 1908, and at first was confined chiefly to a comparison of the porous cup and filter paper voltameters. The larger deposits in the latter form over the former for the same quantity of electricity passing were found to be due to the action of the filter paper on the silver nitrate rather than to the previously supposed fact that the filter paper allowed complex products formed at the anode to pass through and reach the cathode. The excess of deposit was roughly proportional to the quantity of filter paper present.

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* Communicated by the Bureau.

The first series of quantitative measurements was made with the small porous cup form, and the results recorded as the voltage of the Weston normal cell at 20° in terms of the voltameter deposits and the international ohm. The value found for the cell at this period of the work was 1.01828 volts.

PART II.

Following the work recorded in the first paper, efforts were made to determine the nature of the action of filter paper on silver nitrate, and a large number of qualitative experiments were made. Fortunately these were possible, since the appearances of the deposit from pure and impure solutions of silver nitrate were quite different. In the former case the deposit is crystalline, while in the latter the deposit is usually striated and may look like slag under the microscope if the contamination is considerable. The important fact was discovered that if the filter paper merely came in contact with the water subsequently used to make up the electrolyte the resulting deposit would be striated.

Various organic substances, such as starch and cane sugar, produced practically no effect, while cellulose always was active even after prolonged washing. This apparent anomaly led to an extended study of the chemical questions involved, the result of which was to show that the oxycelluloses formed decompose into strong reducing agents, such as furfuraldehyde, and these actually precipitate colloidal silver. The existence of this colloid was fully established.

To account for the change from crystalline deposits to noncrystalline striated formations, a theory has been set forth, based on the two fundamental conditions for striations as found by experiment. These are the presence of colloid in the electrolyte and a motion of the liquid (generally due to convection currents) over the face of the cathode.

PART III.

The qualitative work of the preceding paper was followed by quantitative measurements, using chiefly the small porous cup voltameter, which seemed to be the most reliable form at this time. The result of a long series of measurements was to show that the average deviation of a single cup from the mean of two or three cups used under the same conditions was only one part in 100,000. The mean result of 44 determinations of the voltage of the Weston normal cell at 20° was found to be 1.01827_5, which is in close agreement with the result recorded in the first paper. The difference in deposits on gold and platinum cathodes was shown to be negligible. In general the latter were used. Experiments were also made on the temperature coefficient of the voltameter. This, too, was found to be negligibly small, if not zero, when pure solutions were used. The slightly greater deposit in the large size of porous cup voltameter over the small size was found to be due to impurities in the electrolyte.

The usual methods of testing the neutrality of salts do not apply to silver nitrate, but a method of determining the free acid or base to one part in 1,000,000, using iodeosine as an indicator, was found possible. Tests with $\frac{N}{1000}$ potassium permanganate were also devised to determine the amounts of reducing agents and colloidal silver present in the solution. Much work was expended in learning how silver nitrate of a sufficiently high degree of purity might be obtained, but the process cannot be given adequately in the short space available here.

CORRELATION OF MAGNETIC AND PHYSICAL PROPERTIES OF STEEL.

THE co-operation between the Bureau of Standards and the committee on the magnetic testing of iron and steel of the American Society for Testing Materials still continues. This co-operation in the consideration of specifications and in the carrying on of experimental work prevents needless duplication of work. The standards committee of the American Institute of Electrical Engineers has also agreed to co-operate in this work.

The investigation on the correlation of the magnetic and mechanical properties of commercial steels with a view to discovering some simple magnetic test which may replace some of the mechanical tests and thus avoid the destruction of the material under examination is still in progress. A large amount of data has been collected, and in every case investigated there have been magnetic differences between specimens which had mechanical differences. Without generalizing from the results already obtained, it may be stated that the outlook is very promising. For example, in a certain grade of steel such as is used in springs and tools the magnetic tests showed whether or not it had received the proper heat treatment to give it the desirable mechanical properties.

If the material is not satisfactory, the same magnetic test shows whether the defect is in the nature of too great brittleness or too little mechanical strength. Another test on this same material will show whether it has been subjected to local strains beyond the elastic limit. In another case a steel rail which had broken in service and in which the microscope showed the presence of transverse fissures had a decidedly lower permeability than a similar rail of the same composition which had never been in service and which showed no such transverse fissures. Defects in certain low carbon steel bars have been produced in various ways,—*e.g.,* by bending, nicking, stretching, drilling holes, etc.,—and in every case the good and the defective material have shown characteristic differences.

This work has been carried on with only a limited number of small specimens and by laboratory methods. As this field is almost entirely new, it will be necessary to carry on these preliminary investigations with hundreds of samples, including all the materials that are used in practice. In case the complete investigation fulfils the promise of the part already done, no reason is apparent why the same or similar methods may not be applied to the commercial sizes,—*e.g.,* full-length steel rails.

EFFECTS OF ELECTRIC CURRENTS ON CONCRETE.

By E. B. Rosa, Burton McCollum and O. S. Peters.

Technologic Paper.

THIS paper deals with the results of an extended series of experiments carried out at the Bureau of Standards during the past two years. The investigations consisted of three parts, as follows: (1) Laboratory investigations relating to the nature and cause of the phenomena produced by the passage of electric current through concrete; (2) investigations in the field with a view of establishing the probable extent of the danger in practice, and the circumstances under which the trouble is most likely to occur; (3) a study of the various possible means of mitigating trouble from this source leading to specific recommendations. The experiments were for the most part carried out on cylindrical specimens 6 inches in diameter and 8 inches high with an electrode, usually of iron or other metal, imbedded in the centre, serving as either an anode or cathode in different cases. These specimens were immersed in water in jars surrounded by a sheet-iron electrode, which served as the other terminal.

ANODE EFFECTS.

The tests were carried out with a great variety of voltages, ranging from 2 volts to 115 volts, with the imbedded electrode anode. On the higher voltages, which included all cases having more than about 15 volts per specimen, there was exhibited the familiar phenomenon of cracking of the concrete and rapid corrosion of the imbedded iron, most specimens cracking within 24 hours under a current flow of from 0.5 to 0.8 ampère-hour.

On the low-voltage specimens, however, where the voltages ranged from 2 to 15 volts, very different results were obtained. At the outset of the investigation 90 specimens containing iron electrodes were placed in circuit on 15 volts and watched for a period of seven and a half months. At the end of that time a number were broken open, the amount of corrosion determined, and the general condition of the concrete noted. A most conspicuous feature of the results of this test—and a very surprising one in view of the results previously obtained at higher voltages—is the fact that cracking almost universally failed to occur.

Of the 90 specimens under test only three had cracked at the end of seven and a half months, and these were shown to be abnormal specimens. In practically all cases, also, there was no appreciable corrosion of the iron. It is important to note that the total number of ampère-hours per square inch of imbedded electrode surface in the case of the low-voltage specimens is considerably larger than for the high-voltage specimens, the former averaging 2.6 ampère-hours and the latter only 0.83 ampère-hour. It is evident, therefore, that the quantity of electricity that passes through a specimen does not alone determine the amount of damage that it may do, but that the rate at which the current flows is also an important factor. Moreover, it is evident from these observations that the rate at which damage occurs decreases with decrease in voltage much more rapidly when the voltage is lower, since in the present instance a reduction of voltage to one-fourth of the value used in the high-voltage tests enabled the specimens to run with little or no damage for a period over 200 times as long as was required to destroy the specimens in the higher voltage. It has been shown that this difference in the effect of high and low voltages is fundamentally due to a difference in temperature. So long as the heating effect of the current is insufficient to raise the temperature of the specimen to about 45° or 50° Centigrade, little or no corrosion results, but if the current is strong enough to raise the temperature materially above that point, rapid corrosion sets in.

CATHODE EFFECTS.

When the imbedded electrodes are made cathode, different effects are produced. In this case there is no tendency for the iron to corrode, and the conclusion has been largely accepted that when the current flows from the concrete to the iron no effects were produced. It was found, however, that after such specimens had been in circuit for several months with the iron cathode the bond between the iron and the concrete was practically destroyed. On laying the specimens open it was found that the entire region surrounding the cathode for a distance of one-sixteenth to one-fourth of an inch from the surface of the metal was considerably darker in appearance than the main body of the concrete, and was very soft. The cement here could be shaved off with a knife like soft soapstone.

Experiments with concrete containing no reinforcing material showed that the flow of comparatively heavy currents through the concrete produced no appreciable effect on its mechanical properties. The effects noted above are therefore solely electrode effects, and the softening of the cement at the cathode is attributed to the concentration of sodium and potassium hydroxide near the surface of the cathode, and it is this that causes the softening of the cement. The cracking of the concrete when the iron is anode is due to formation of oxide of iron, and the swelling action thus gives rise to a mechanical pressure which cracks the specimen. The pressure thus produced was measured in several instances and was found to reach values of over 3700 pounds to the square inch.

RISE OF RESISTANCE OF CONCRETE.

It was found that in all cases the resistance of the concrete rose greatly, due to the passage of electric current, the rise being greater in anode specimens than in cathode specimens, the former showing an average increase of 137 times the original value at the end of seven and a half months, and the latter showing an average increase of 14 times the original resistance at the end of about the same period.

The addition of a small quantity of salt to the concrete produced very marked effects. Two or three per cent. of salt added to the water used in mixing the concrete caused the anode specimen to be destroyed very quickly even on very low voltages, because of rapid corrosion of the iron, and also greatly increased the rate at which the softening of the cement at the cathode progressed. The addition of salt likewise reduces the initial resistance of the concrete, and, more important still, prevents the rise of resistance which otherwise takes place under the influence of the electric current.

In discussing the possibilities of trouble from electrolysis in concrete structures under practical conditions, it is pointed out that, while the dangers from this source have often been greatly exaggerated, the possibilities of trouble are nevertheless sufficient to make precautionary measures necessary under many circumstances. A number of possible precautionary measures are discussed in the last section of the paper.

The French Photographic Society announces its fourth competition in color photography, which is open to all photographers, amateur and professional. All classes of work may be submitted, including subjects for window transparencies, lantern slides and stereoscopes. Prints should be accompanied by a description of the subject they represent and the conditions under which they were taken. Numerous medals will be awarded by the jury. The entries close on April 15th next.

Color Photography and Printing. G. BANGÉ A. DUMEZ, and A. DE SEAUVE. (*Eng. Pat. 20,251,* Sept. 12, 1911.)—A set of three color filters is prepared by the use of the following solutions (the quantities are those required for one square metre): *Red,* 64 c.c. of 1 per cent. erythrosin solution, or 10 c.c. of 1 per cent. Bengal Pink solution; *yellow,* 115 c.c. of 1 per cent. Tartrazine solution; *blue,* 5 c.c. of 1 per cent Carmine Blue and 1 c.c. of 1 per cent. Naphthol Green solution. Each filter is also impregnated with about 10 grammes of potassium nitrate per square metre. In conjunction with these filters positive films are employed which can be sensitized with bichromate, the red film consisting of gelatin stained with madder lake and spread on paper to the extent of 8.5 grammes per square metre; the yellow film is impregnated with cadmium sulphide, spread to the extent of 12.8 grammes per square metre, and the blue film is obtained by precipitating a solution of a ferric salt(*e.g.*, by ferrocyanide) and mixing the precipitate with gelatin, using about 6 grammes per square metre. A series of scales of primary colors and of gray, which are photographed at the same time as the subject of the pictures, is also used to check exposures and development of the photographs. The positive films are prepared on paper which has been parchmentized by sulphuric and nitric acid and subsequently dipped in a solution of gum-lac in alcohol.

Variations in Temperature Coefficients of a Precision Balance. J. J. MANLEY. (*Roy. Soc. Proc., Ser. A,* lxxxvi, 591.)—In a previous paper the apparent abnormal behavior of certain precision balances was described and discussed. One point dealt with the displacement of the resting-point of a beam, dependent upon a uniform rise or fall in the temperature of the instrument. The amount of such displacement for a change of 1° C. was termed the "temperature coefficient" of a balance. In this paper attention is directed to changes which may occur in the temperature coefficients of delicate balances. Peculiarities noted with a new balance disappeared after continued careful use of the balance. The conclusion is drawn that before a new, or comparatively new, precision balance can be safely used for obtaining trustworthy values of the highest order of accuracy the instrument must be suitably "aged." A method of effecting this is suggested.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, March 19, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 19, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 6.

After the transaction of the usual Institute business a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, President Clark and Chairman Hornor presiding jointly.

The paper of the evening, entitled "The Generation and Distribution of Energy," was presented by Mr. Samuel Insull, President, Commonwealth Edison Company of Chicago.

The speaker described in detail the progress in the economical generation and distribution of electrical current to cities, country towns, and farming communities, and for the drainage of land, power in mines, propulsion of cars on interurban railroads, and other purposes.

He pointed out that economy in the manufacture and distribution of electrical energy is only possible by concentration of production, distribution, and administration.

Numerous lantern slides were shown which gave statistical and other information relating to electrical distribution and consumption.

After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March* 5, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 5, 1913.

MR. J. A. P. CRISFIELD *in the Chair.*

The following report was presented for final action:

No. 2523.—Ellis Adding Typewriter. Scott Award recommended. Adopted.

The following report was presented for first reading:

No. 2529.—The Work of Albert Sauveur in Connection with the Metallography of Iron and Steel.

The following applications were accepted for examination:

No. 2530.—Stumpf's Una-Flow Steam Engine.

No. 2531.—Barr's All-Glass Fruit and Preserve Jar.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on the evening of March 6, at 8 o'clock.

Dr. George A. Hoadley occupied the chair.

The Chairman introduced Dr. Arthur W. Goodspeed, Professor of Physics, University of Pennsylvania, member of the Institute.

Dr. Goodspeed gave an instructive lecture on "Electricity and Matter."

He approached his subject by reviewing the work of Sir William Crookes on electrical discharges in high vacua; of Lenard, Hittorf, and Thomson in the same field, and then of the Curies with radium. He showed how this early work led to the theory of the existence of both molecules and electrons.

Dr. Goodspeed gave several experimental demonstrations, one being to show the interception of radium emanation by a fluorescent body in a bath of liquid air.

Several members of the audience questioned Dr. Goodspeed at the close of his remarks.

The thanks of the meeting were extended him.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the section was held on Thursday evening, March 13, 1913, in the Hall of the Institute, at 8 o'clock.

Dr. Harry F. Keller presided.

The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. Arthur D. Little, Chemical Engineer; president Arthur D. Little, Inc., Boston, Mass., who presented an interesting and instructive communication on "The Chemistry of Paper Making."

Mr. Little reviewed the history of the art from the early times of the making of hand-made paper in small sheets to the present manufacture of this substance by improved machinery and highly-developed processes.

He spoke of the methods of manufacturing the various grades of paper; of processes of starching, glazing, coloring, and otherwise treating the product.

An explanation of methods of watermarking and an exhibition of samples of fine production from Russia and Italy proved very interesting.

The speaker enumerated the uses of paper, and made some remarks on the future of the paper-making industry.

His talk was illustrated by lantern slides and exhibits.

After a brief discussion, the thanks of the meeting were extended Mr. Little.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

JOHN FRITZ.
1822–1913.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting of the Board of Managers, March 12, 1913.*)

RESIDENT.

MR. MORRISON COATES NELL, 918 Stephen Girard Building, Philadelphia, Pa.

NON-RESIDENT.

MR. HOWARD N. EAVENSON, Gary, W. Va.
MR. ALBERT R. SHIPLEY, 29 Arch Street, Providence, R. I.
MR. THOMAS TAPPER, 362 Riverside Drive, New York City, N. Y.

ASSOCIATE.

MR. THEODORE W. PINARD, 529 Penn Street, Camden, N. J.

Changes of Address.

MR. WILLIAM C. FARNUM, 131 Oak Street, Winchendon, Mass.
MR. FRANK B. GILBRETH, 71 Brown Street, Providence, R. I.
MR. EDWIN P. GOTWALS, 335 North Broad Street, Lansdale, Pa.
MR. GEORGE R. HALL, 35 Fort Washington Avenue, New York, N. Y.
MR. J. M. HOPWOOD, 98 Fifteenth Street, Wheeling, W. Va.
MR. HUGO LIEBER, 25 Madison Avenue, New York, N. Y.
MR. FRANK G. STANTIAL, 146 Florence Street, Melrose, Mass.
MR. THOMAS TAPPER, 362 Riverside Drive, New York City, N. Y.

NECROLOGY.

JOHN FRITZ.

1822–1913.

In 1910 The Franklin Institute conferred the Elliott Cresson Medal upon John Fritz for "distinguished leading and directive work in the advancement of the iron and steel industries," an additional honor to the many testimonials he received for his engineering ability. He served as president of the American Institute of Mining Engineers and of the American Society of Mechanical Engineers, and was an honorary member of the American Society of Civil Engineers, The Franklin Institute, and other associations. He was chosen vice-president and awarded the Bessemer Gold Medal by the Iron and Steel Institute of Great Britain, and was the first to receive the John Fritz Gold Medal established by the National Engineering Societies.

Born in 1822, he received merely the common-school education which at that time was obtainable in country districts of Pennsylvania, and from early youth he earned his living; but what he undertook he did well, and used his brain as well as his hands to improve methods and processes in iron manufacture. Possibly the best epitome of his achievements was at the celebration of his 70th birthday, when at a mock trial he was indicted for "being a distinguished engineer without technical training"; for he was a good engineer and had not the advantages of technical education.

Although a notable instance of what can be accomplished by individual ability and conscientious effort, John Fritz recognized the value of a thorough education, aiding many to improve themselves and demonstrating his interest by service as a trustee of Lehigh University, supplemented by the Engineering Laboratory, which he built and endowed at an outlay of nearly a quarter million dollars.

His life-work was in iron and steel production and manufacture, some of the most important inventions in this specialty representing the ingenuity of John Fritz. He saw iron production in its infancy; saw it pass from the charcoal into the anthracite and then to the coke era; and saw the production of a blast furnace grow from a few tons to several hundred tons per day. The introduction of the Bessemer and the development of the open-hearth steel processes; the transition from the forge fire or puddling furnaces to gas-fired furnaces of large capacity; from the slitting mill to immense roll-trains, fabricating heavy beams, rails, plates, etc., and from water-operated trip-hammer to hydraulic presses manipulating heavy forgings under pressure rated at thousands of pounds per square inch, are merely some of the advances with which John Fritz was personally familiar and in the development of which he participated.

The presence at his funeral of hundreds of men, representatives of technical societies and of varied industries, evidenced appreciation of his abilities and achievements, and the cessation of industries, the closing of business houses and schools, the funeral escort of the student body of Lehigh University, were tributes of love in his home town, Bethlehem, where he had long resided and where, in his 91st year, he died, honored and revered by all.

J. B.

LIBRARY NOTES.

Purchases.

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ROYLE, H. M.—The Chemistry of Gas Manufacture. 1907.
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CURRENT TOPICS

Penetration of Canal Rays into Solids. J. Stark and G. Wendt. (*Ann. d. Physik.*, xxxviii, 921.)—Several pages are occupied in stating the problem and in its theoretical consideration, and sketches of the apparatus are given. Hydrogen canal rays of kathode-fall up to 5000 volts scatter the *smooth* surfaces of calcspar, fluorspar, glass, and quartz; but they do not destroy the polish. Plates of rock-salt, sylvine, and mica are perceptibly roughened by the impact of slow canal rays. Canal rays of kathode-fall greater than 10,000 volts roughen the surface of fluorspar, calcspar, glass, sylvine, mica, and rock-salt. The surface of quartz is not roughened, yet there is considerable scattering. With calcspar mercury canal rays produce a chemical change in the surface, due to the heating effect; they also produce a scattering effect in all the substances submitted to experiment, without causing a roughening of the surface at the point of impact. The mechanical deep action of the hydrogen canal rays cannot be ascribed to the penetration of the rays through the inter-molecular valency fields under the surface layer. Solid metals are dulled by slow hydrogen canal rays through scattering. The surface of the base of a bismuth crystal is not perceptibly roughened by slow canal rays, and only very slightly by rapid rays; the rays have a much greater scattering effect upon a surface whose plane is approximately perpendicular to this direction.

The Gelatinizing Temperature of Starch Granules. M. Nyman. (*Zeit. Unters. Nahr. Genussm.*, xxiv, 673.)—Rye, barley, and wheat starches gelatinize at slightly different temperatures,—rye starch at 57° C., barley starch at 58° C., and wheat starch at 59° C. The determinations were effected by placing the starches in water heated to the suitable temperature and, as the temperature rose, removing drops of the mixtures every 30 seconds for examination under the micro-polariscope. The points at which the granules ceased to show interference crosses was taken as the gelatinizing temperature. Experiment showed that the larger starch granules gelatinized more quickly than the smaller. Although the difference in the gelatinizing temperature does not afford a means of identifying two starches in a mixture, the rate of gelatinization may be of some value. For instance, if a mixture of rye and wheat meals is held at 53° C., the rye starch is gelatinized in 6 minutes, while the wheat starch requires 24 minutes; any ungelatinized grains observed after 7 minutes' heating indicate the probable presence of wheat meal.

Active Modification of Nitrogen Produced by the Electric Discharge. R. J. STRUTT. (*Roy. Soc. Proc., Ser. A,* lxxxvii, 179.)—Certain previous observations appeared to suggest that the chemical peculiarities of active nitrogen might be due not to the presence of a definite chemical substance but to the unexplained survival of the conditions of disruptive discharge. Further investigation supports the original view, however. When the active nitrogen is passed through a vacuum-jacketed tube containing a roll of oxidized copper gauze, the gauze becomes heated by the reversion of the active to the ordinary nitrogen, particularly when nitric oxide is mixed with the nitrogen, while the temperature falls if oxygen is admitted instead of nitric oxide. Ionization experiments show that the intensity of the glow is not affected by the removal of the ions, and therefore it is not probable that it is produced by the ions. Local cooling intensifies the glow by accelerating the change, which is proved by dipping a bulb with its tubular neck into liquid air. Hence the active nitrogen appears to be a highly endothermic body, the energy of which is of the same order of magnitude as that of other chemical substances. The ionization is a subordinate effect and might be due to light of very short wave-length emitted during the reversion to ordinary nitrogen; the number of the ionized atoms is a very small fraction of the whole number of atoms concerned in the change. It is suggested that the active nitrogen is monatomic, and that the phenomena may throw light on the connection between temperature and the velocity of reaction.

Heat Transmission. C. H. LANDER and J. PETAVEL. (*Elect. Rev.,* lxxi, 530.)—Describes experiments on the heat lost by hot metal cylinders to surrounding air, the results being applicable to the lagging of steam pipes. The various conditions under which convection, conduction, and radiation assume importance are discussed. All lagging materials conduct better than air and increase the loss due to conduction. They should therefore be packed loosely so as to hold air round the pipe. The lagging can be too loosely packed, as is shown by an experiment on slag-wool lagging of varying densities. The best result is where the wool occupies one-fourteenth of the total space. The loss by radiation per square foot from small pipes diminishes rapidly as the diameter increases, but above 4 inches diameter it becomes nearly constant.

Uses of Peat for Fuel and Other Purposes. C. A. DAVIS. (*Bureau of Mines, Bull No. 16.*)—A comprehensive paper, the scope of which may be thus indicated. The main sections are: Origin and formation of peat; physical and chemical properties of peat as related to its fuel value; preparation and manufacture of peat fuel; peat as a raw material for products other than fuel; tables of analysis; bibliography of peat. For those interested this bulletin is of considerable value.

Naphthalene as Fuel for Explosive Engines. L. VENTON-DUCLAU. (*Mem. et Compte. Rendus des Trav. Soc. Ing. Civ. de France,* lxv, 514.)—Its low price as compared with other hydrocarbon fuels suggests the use of naphthalene. Its percentage of carbon is 93.7, as compared with 92.3 for benzene, and the quantity of air required for the complete combustion of 1 gramme is 13.34 grammes, as against 13.04 grammes for benzene. Since the melting point of naphthalene (79° C.) is well above atmospheric temperature, a special apparatus is required to obtain the explosive mixture of air and naphthalene. The advantages are: (1) low cost, which may be only 0.65 cent per horsepower-hour; (2) security from fire, since naphthalene is only ignited with difficulty even in the liquid state, and a leak of the liquid is not dangerous, as it immediately solidifies; (3) uniformity of composition, as naphthalene is a definite compound. The heat required for melting and vaporizing the naphthalene is obtained from the cooling water or the exhaust gases of the engine, and the engine must be run for the first few minutes with a light fuel, such as petrol, until the parts are warmed up. Hence naphthalene is not suitable where stoppages of any substantial duration occur. Naphthalene has been chosen for fuel for locomotives on the Trans-Siberian Railway, where the water contains fully 5 per cent. of salts. Carburettors for naphthalene are of two principal kinds: (*a*) using naphthalene dissolved in liquid fuel, and (*b*) using melted naphthalene. In type *a* the solid naphthalene is carried in a cage which can be dipped into a reservoir of benzene, alcohol, petrol, etc., the liquid being heated by the engine cooling water or by the exhaust gases. In type *b* the liquid may issue from a spraying nozzle, or the air may be bubbled through the liquid, or the liquid may drop on a heated surface in the air pipe. A single cylinder engine of 140 millimetres diameter and 200 millimetres stroke, fitted with a Bruneau carburettor, used fuel costing about $18.25 per ton. A two-cylinder engine, with cylinders 88 by 140 millimetres, fitted with a Noel carburettor, used fuel costing about $14.25 per ton.

Steam Turbo-generators. ANON. (*Elect. World,* lx, 716.)—*Report of Committee of Assoc. of Edison Illum. Compounds.*—This recounts the progress lately made in designing and arranging steam turbines. The upper limits of speed, outfit, etc., are recorded and compared with the figures obtained a year ago with frequencies of 25 and 60. Special attention is directed to the methods of the Westinghouse Company—*e.g.*, in the improved ventilation of the generators, in the design and construction of the rotors and their winding and insulation, in the maximum voltage (up to 13,000 volts) used directly on the armature windings, and in the means used for bracing the end windings with more security. There is also a description of the means used for supplying cooling air to the generators by blowers or other methods.

Cobalt-chromium Alloys. E. HAYNES. (*Met. and Chem. Eng.*, x, 804.)—Tungsten alloys readily with chromium and cobalt in all proportions, but has little influence in small quantities; above 3 per cent. the alloy becomes harder and more elastic, especially in the presence of small quantities of carbon, boron, or silicon. When the chromium is kept at 15 per cent. a forgeable alloy suitable for cold chisels and wood-working tools is obtained when the tungsten reaches 10 per cent. As the percentage of tungsten rises to 20 per cent. the forgeability decreases, and at 25 per cent. it becomes a very hard alloy, which cannot be forged to any extent, but can be cast into bars and ground to forms suitable for lathe tools, which are very strong and retain their hardness at speeds which instantly destroy the cutting edge of steel tools. An alloy with 40 per cent. of tungsten readily scratches quartz and will turn up, in a lathe, 49 cast-iron wheels without losing its edge; in the same time a steel tool will do only 26 similar wheels, and has to be ground 50 times during the operation. Alloys with similar properties are formed by adding molybdenum to a similar cobalt-chromium alloy. A smaller quantity of molybdenum than of tungsten is required to produce the same increase in hardness.

Philippine Guano. A. J. COX. (*Phil. J. Sci.*, vii, 195.)—Large quantities of phosphate guanos occur in the Philippine Islands, chiefly in limestone caves; the deposits in some caves are reported to reach thousands of tons. The guano is generally bat guano, granular in appearance and gray to brown in color. Its chemical composition is very variable. Good specimens have been found to contain nearly 9 per cent. of nitrogen and over 5 per cent. of phosphoric anhydride and about 1 per cent. of potassium oxide. It is only in unusually dry and well-protected places that the guano remains unleached. In many places the guanos have lost a great part of their soluble constituents (ammonium salts and uric acid), and their value as fertilizers, as given by analysis, is greatly lower than that of the sample quoted above.

Preparation of Natto. S. MURAMUTSU. (*J. Coll. Agric. Imp Univ. Tokyo*, v, 81.)—Natto is a kind of vegetable cheese made by fermenting boiled Soya beans wrapped in rice straw and set in a warm cellar for a few days. The product develops bacteria and becomes white and mucilaginous. It is eaten mixed with condiments. The bacteria are on the surface of the beans, and their spores are not killed by boiling. The straw is used to "supply the good aroma of straw to natto, to take away ammonia," and to facilitate the free access of air to the loosely-packed beans. Three bacilli have been isolated in pure culture with which natto of three qualities can be produced. The mean composition of the dry matter of natto, which amounts to 46.5 per cent., is protein 46, fat 20, fibre 6, nitrogen free extract, 3.3, and ash 5 per cent.

Simplicity of the Entropy Chart. W. J. CRAWFORD. (*Power*, xxxvi, 600.)—The simplicity of the entropy chart is emphasized and its more general use is urged. The simplest form of entropy chart (without volume and heat-unit lines) is illustrated, and its use is shown by a number of examples and sketches giving those parts of the whole chart concerned in each case. These examples include the determination of the dryness fraction of steam expanded adiabatically from a stated initial condition (wet, dry, or superheated); the determination of initial dryness (knowing the dryness fraction); determination of the final degree of superheat and of the initial superheat (knowing the final dryness fraction). The representation of a Rankine cycle on the entropy chart is illustrated. The more complex charts used in practice are more confusing at first sight, but are actually more labor-saving.

Ternary Alloys of Magnesium, Zinc, and Cadmium. G. BRUNI and C. SANDONNINI. (*Zeit. anorg. Chem.*, lxxviii, 273.)—Herein are given the results of a micrographic investigation of the ternary alloys of magnesium, zinc, and cadmium. The binary zinc-cadmium alloy shows a eutectic point at 262° C., with 26.5 atomic per cent. of zinc. The cadmium holds about 2 atomic per cent. of zinc in solid solution. Magnesium and zinc form a compound, $MgZn_2$ (melting point 589° C.), and two eutectics, containing respectively 7.5 atomic per cent. of magnesium (melting point 363° C.) and 72 atomic per cent. of magnesium (melting point 340° C.). Magnesium and cadmium give a compound, MgCd (melting point 424° C.), which forms an unbroken series of solid solutions with both components. The compound MgCd exists in two forms, the transition temperature being 248° C. The ternary system has only one true triple eutectic point (250° C., 73 atomic per cent. Cd, 25 Zn, and 2 Mg), and may be divided, as regards primary crystallization, into three areas. The largest range of alloys, covering over two-thirds of the triangular diagram, is that which gives the compound $MgZn_2$. A narrow strip covering about one-fifteenth of the triangle corresponds to primary zinc separation, while the remainder is a region in which a solid solution is the first product to separate. The number of alloys studied was nearly 200, and the paper is illustrated by 40 photomicrographs, which are described and discussed.

Radioactive Elements in Cosmical Systems. S. A. MITCHELL. (*Astronom. Nachr.*, No. 4600.)—The spectra of the sun's atmosphere obtained during the total solar eclipse on August 30, 1905, have been carefully examined for evidence of spectrum lines of radium, the emanation and uranium, as recently suggested by Giebeler and Kayser with regard to the spectrum of Nova Geminorum. No evidence of the presence of the radioactive elements was detected.

Photolysis of Various Classes of Sugars by Ultra-violet Rays. D. BERTHELOT and H. GAUDECHON. (*Comptes Rendus*, clv, 1153.) —The photolysis of ketoses may be effected with rays of longer wave-length than 0.3μ; for aldoses the upper limit is 0.3 to 0.25μ; for open-chain polyhydric alcohols the upper limit is 0.25 to 0.2μ, while cyclic polyhydric alcohols are only decomposed by the extreme ultra-violet rays, of wave-length less than 0.2μ. When these classes of compounds are submitted to the action of rays of the longest wave-length which will effect photolysis, the decomposition proceeds in a simple fashion. From ketoses only carbon monoxide is evolved; from aldoses, two volumes of carbon monoxide and one volume of hydrogen; and from polyhydric alcohols, equal volumes of these two gases. There is no formation of acid nor of substances capable of reducing Fehling's solution in the cold. When, however, rays of shorter wave-length are employed, the product develops acidity and does reduce cold Fehling's solution. At the same time there is an increased production of hydrogen, and some carbon dioxide is formed. Very advanced decomposition causes methane to be produced. Sunlight decomposes ketoses fairly readily, but aldoses only slightly. Solutions of erythritol and mannitol exposed to sunlight for six months evolved no gas, but acquired slight reducing properties. Carbon monoxide and hydrogen, which are primarily formed in simple proportions by the photolysis of carbohydrates, have been shown to combine under the influence of ultra-violet light to produce formaldehyde, the starting point in the natural synthesis of carbohydrates. The photolysis and photosynthesis of formaldehyde are probably reversible processes, and this appears to be true in the case of sugars generally.

The Weighting of Silk with Tin-phosphate. H. LEY. (*Chem. Zeit.*, xxxvi, 1405, 1466.)—Sisley's theory of a preliminary mechanical absorption of the tin-chloride is accepted, but it is suggested that the tin-chloride then undergoes a chemical change within the silk substance, becoming converted into hydroxide, which is at once capable of further chemical combination with the tin-chloride of the bath, forming an insoluble oxychloride. This accounts for the increase of weight with successive baths of "pink-salt," which would not result from mere impregnation. This increase is not mathematically regular, probably owing to the production of a more or less basic tin oxychloride within the silk fibre. The phosphate weighting is regarded as a further chemical reaction, first converting stannic oxide to sodium stannate and then reacting with the free phosphoric acid to form mono-stannic, di-stannic, or tri-stannic phosphate. It is important, from the commercial viewpoint, to remember that the phosphate bath often contains tin salts (*e.g.*, sodium stannate and colloidal tin hydroxide) which are detrimental to the sheen and durability of the silk.

A Speaking Incandescent Lamp. Anon. (*Sci. Amer.*, cvii, 25, 527.)—It has been lately discovered that under certain conditions the incandescent lamp may be made to speak as readily as the arc lamp. According to the *Physikalische Zeitschrift,* Messrs. K. Ort and J. Ridger have used a metal filament lamp as a telephone receiver, employing an Osram lamp of 100 candle-power. The lamp is placed in a 120-volt direct-current circuit including a self-induction coil. Shunted across the two terminals of the lamp are a capacity and the secondary of a telephone transformer, the primary of which connects with a battery of five storage cells and a powerful microphone. Words spoken before the microphone are reproduced in the lamp. The discoverers of this speaking incandescent lamp explain the action on the principle that the telephonic current variations superposed on the current that passes through the lamp produce corresponding variations of heat in the filament, which, radiating to the glass of the bulb, cause the latter to expand and contract proportionately and thus transmit the vibrations to the external air. The effect cannot be produced with 16 or 32 candle-power lamps, because the glass is too thick and the heat variations too feeble.

Vaporization of Metals. J. W. Richards. (*Trans. Amer. Inst. of Metals,* 1912.)—Metals have vapor tension curves similar to that of water. Like ice, the metals have some vapor tension in the solid state. Zinc, boiling at 920° C., has an appreciable vapor tension at 289° C., or 130° C. below its melting point. Silver can evaporate from solid ingots if heated in a flame; the gases carry off some silver vapor. An effective way of checking such volatilization losses is by heating in closed vessels, and especially by the use of the electric furnace.

Rose Culture and the Manufacture of Oil of Roses in Bulgaria. P. Siedler. (*Ber. Deut. Pharm. Ges.*, xxii, 476.)—White and red roses are grown; the former are the easier to cultivate, but give only about half as much oil of an inferior quality. The individual growers distill their own oil. Twelve to fifteen kilos. of roses are distilled with sixty kilos. of water until twelve kilos. of distillate are obtained; about eight or nine such lots are mixed and redistilled into flasks with long necks, in which the oil collects on standing. One kilo. of oil is obtained from 3000 kilos. of roses, and 400 roses weigh one kilo. The roses are gathered in the early morning and distilled the same day; usually a mixture of the two kinds is distilled. The pure oil varies in odor and physical properties according to the district in which it is grown, and is skilfully blended by the distributing houses before its sale. The oil is usually adulterated by the peasants, who mix in ginger-grass oil, palma rosa oil, geranium oil, and several other oils. In 1910 there were 3148 kilos. of oil produced.

On the Origin of Planets and their Satellites. BIRKELAND. (*Mon. Sci.*, lxxviii, 853, 64.)—Guided by experimental analogies, M. Birkeland has been led to believe that in the solar systems now in evolution there exist certain forces of electromagnetic origin of the same order of magnitude as that of gravitation, and that these forces, acting in concert, have given birth around the sun to planets having nearly circular orbits, situated approximately in the same plane, to the moons, and to the rings around the planets, and to the nebulæ both in the shape of rings and spirals. The most distant moons, recently discovered near Jupiter and Saturn, with their *retrograde* revolution, do not invalidate this theory; on the contrary, this retrogression suggests that if new planets are discovered sufficiently distant from Neptune, they, too, should have a retrograde revolution around the sun. As the fundamental supposition it is affirmed that all the suns, in comparison with the space of the universe, have an enormous electronegative tension, which differs for the various stars, but which, to give an idea of its magnitude, approximates 600,000,000 volts for our sun and for all suns of a similar class. By means of experimental analogies he endeavors to show how a magnetic field can thus form itself around a star, with its axis the length of its axis of rotation, and how the electric discharges issuing from the central body would, by preference, produce themselves around the equatorial magnetic plane with a continual projection of material electrified particles, which continue their course in the same plane.

The Effect of Acids and Oils on Concrete. W. L. GADD. (*Engineering*, xcv, 20.)—Even exceedingly dilute mineral acids dissolve some of the constituents of Portland cement. Organic acids have less effect, but they combine with the calcium hydroxide liberated when the cement is gauged with water. The author's experiments lead to the conclusion that the addition of oil or fat of any kind to concrete weakens it. Animal and vegetable oils have a direct action on green concrete and finally destroy it, owing to the saponification of glycerides by calcium hydroxide. Indurated concrete is not attacked to the same extent. Mineral oils, though there can be no saponification in this case, weaken mortar to some extent, even when only small proportions of oil are used, and the resulting concrete is less waterproof than dense mortars in which the aggregates are properly graded to fill the voids.

Egypt's Debt to the Engineer. ANON. (*Sci. Amer.*, cvii, No. 23, 477.)—The Assouan dam and other irrigation works in Egypt have cost about $53,000,000; but the increase in the value of land in middle and lower Egypt and the Fayum provinces has been from $955,000,000 to $2,440,000,000. The total rent of this land has risen from $82,000,000 to $190,000,000. This is what the engineer has done for Egypt in less than twenty years.

Photolysis of Various Complex Sugars (Bioses and Trioses) by Ultra-violet Rays. D. BERTHELOT and H. GAUDECHON. (*Comptes Rendus,* clv, 1506.)—Ten per cent. solutions of maltose and lactose exposed to sunlight ($\lambda > 0.294\mu$) for six months suffered no change. When exposed to ultra-violet rays of relatively long wave-length ($\lambda > 0.25\mu$) there was decomposition in two stages, and gases were evolved, two volumes of carbon monoxide to one volume of hydrogen. The solutions remained neutral, did not reduce Fehling's solution in the cold, and had only a slight effect on ammoniacal silver nitrate. When exposed to the extreme ultra-violet radiation the solutions became acid and strongly reducing, and carbon dioxide and methane were among the gases evolved. The gases from maltose contained: carbon monoxide 29, hydrogen 51, carbon dioxide 14, and methane 6 per cent. Lactose, trehalose, and gentiobiose gave almost the same proportions. Trioses are decomposed by the radiation of longer wave-length into two molecules of aldose and one of lævulose, the composition of the gas being approximately three of carbon monoxide to one of hydrogen. This was also observed with raffinose, melezitose, and gentianose. When the rays of shorter wave-lengths are used the composition of the gases changes in the same respects as in the case of the bioses. It is suggested that, since ultra-violet radiations can perform all the functions of enzymes in the scission of sugars and of fats, the reason for the action of enzymes is not to be sought in their chemical structure, but in their vibratory rhythm.

Waterglass Sandstone. W. PUKALL. (*Sprechsaal,* xlvi, 1.)—In 1894 the author concluded that old Persian tiles consisted of a sandstone, and not of a clay, body. Burton has recently come to the same conclusion with regard to old Egyptian ware. Heinecke and Eisenlohr have reached a similar decision in their examination of the tiles in the Omar mosque at Jerusalem. To manufacture these bodies so as to successfully withstand European climates, it is necessary to reproduce artificially the richly alkaline, non-aluminous sandstone. This mixture is recommended: fine sand 100 parts, soda crystals 9, waterglass (of specific gravity 1.38) 12, water 4 parts by weight. The mass is submitted to hydraulic pressure and burned at cone 05. It undergoes a linear contraction of 4.7 per cent., which increases to 8.8 per cent. at higher temperatures.

Amyl Acetate in Bananas. C. KLEBER. (*Amer. Perfumer and Essent. Oil Review,* vii, 235.)—The pulp from a bunch of bananas was distilled with steam and a few drops of oil obtained with a strong banana odor. The oil was hydrolyzed with an aqueous solution of sodium hydroxide and then oxidized with permanganate solution, which produced valeric acid. As silver acetate was obtained from the alkaline aqueous liquid from hydrolysis, the presence of amyl acetate in the original oily distillate was inferred.

India-rubber Production in 1912. S. FIGGIS AND CO. (*London.*) —In 1912 the world's supply of rubber was about 92,000 tons, or, if guayule be included, 99,000 tons; in 1911 the production was 88,000 tons. About 950,000 acres are producing rubber in the East, and about 80,000 acres in Mexico, Nicaragua, and Honduras. The exports from Brazil, Bolivia, and Peru were 50,720 tons in 1912, against 44,170 tons in 1911; about 1000 tons of guayule were exported from Mexico last year. Exports from Ceylon and India amounted to 6300 tons, from Malaya 22,200 tons, and from the West African Coast about 13,800 tons. Imports of rubber into England were:

	Imports. Tons.	Deliveries. Tons.	Stocks, Dec. 31. Tons.
1910	32,659	29,980	5231
1911	33,964	34,054	3954
1912	43,853	44,238	3569

Imports of Parà (Manaos) rubber into England were 11,377 tons in 1912, 11,726 in 1911, and 12,433 tons in 1910, and of Peru (Cauchu) 3792 tons in 1912, 3753 tons in 1911, and 5577 tons in 1910. Of East India and Malay plantation rubber 21,211 tons were imported into England in 1912, as compared with 10,656 tons in 1911 and 6598 tons in 1910.

Pebbles Carried by the Wind. ANON. (*Sci. Amer.*, cviii, 1, 17.)—It has been shown that a wind with a velocity of 23 metres per second can transport through the air particles of sand not exceeding 2 millimetres in diameter. Yet occasionally "rains of stones" of much larger size have been observed. Thus a fall is recorded in the Canton de Vaud of stones of 1½ centimetres in diameter and weighing up to 2.62 grammes. The nearest region whence they could have come was Maures and Esterel. In Château Landon small calcareous stones of 3 centimetres diameter were carried 150 kilometres. In 1883, in Sweden, stones as large as filberts, enveloped in large ovoid hailstones, and weighing nearly 6 grammes, were carried 60 kilometres. Such cases are discussed by M. Thoulet in *Les Annales de l'Institut Océanographique,* and a plausible explanation is suggested. The idea must be accepted of some sort of fixation around the pebbles of an envelope of air or of water vapor. The density of the transported body would then not be that of the pebble but that of the mass of combined solid and fluid (or gaseous) matter, which would be sensibly lighter with respect to its volume.

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ENGINEERING APPLICATIONS OF THE GYROSCOPE.[1]

BY

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THE general phenomenon of a freely suspended rotating body, or gyroscope, has been very much obscured by its mathematical friends. Volume after volume of mathematical deductions have been compiled in an attempt to investigate and analyze the numerous gyroscopic reactions and their various ramifications. This interminable labyrinth of formulæ has given the world the impression that the phenomenon of freely suspended rotating bodies is so intertwined with theory as to be of little practical value. I am sure you will agree with me that this is very far from the truth when I have explained to what excellent uses it is possible to put these reactions.

The French scientist Foucault was the first to deduce any practical laws covering the reactions of the gyroscope. This he did in the year 1851, when he astonished the scientific world by demonstrating that the inertia of a rapidly rotating wheel was relative to space, and that the rotation of the earth could consequently be shown by this means.

Lieutenant-Commander Obry, an Austrian naval officer,

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[1] Presented at the stated meeting of the Institute, held Wednesday, January 15, 1913.

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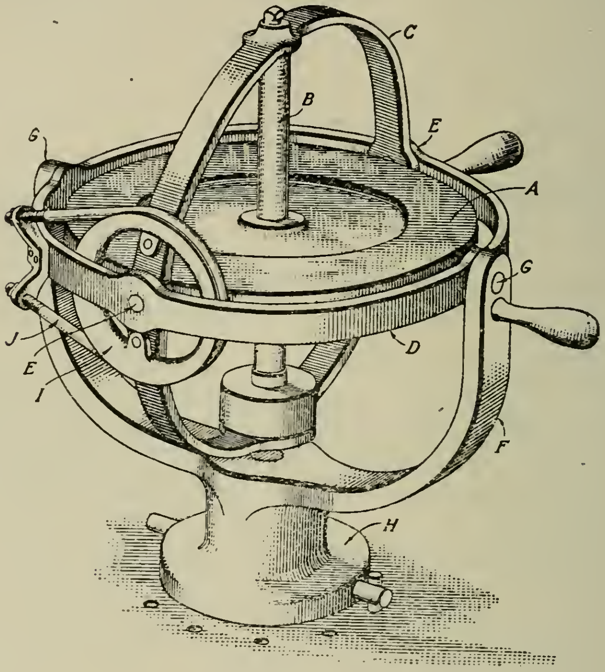
made the first practical application of the gyro by using it as a means for steering a torpedo. Before that time the torpedo was little more than a possibility in warfare, but since that time the gyro gear has been very highly developed and has been the most potent factor in making the torpedo an efficient instrument of war.

FIG. 1.



A simple gyroscope.

Although the many mathematicians who worked over the phenomena became involved in endless abstraction, the phenomenon is, nevertheless, very simple, and the engineering calculations necessary to its practical application are perfectly concrete and easily followed. The phenomenon can be clearly understood by referring to Fig. 1, which is a gyroscope suspended with three degrees of freedom; *i.e.,* freedom about its axis of rotation; *B*. freedom about the axis *G—G* and freedom about the axis *E—E*.

If the band *J* be securely clamped about the ring *I*, attached to the ring *C*, freedom about the axis *EE* would be suppressed and the gyro would then be said to have a suspension with "two degrees of freedom."

Suppose the clamp *J* in Fig. 1 is released and the wheel *A* is rotating rapidly, with the side nearest the observer moving from right to left. If a force be impressed on the near side of ring *D*, tending to push that side downward about the axis *GG*, this force will be resisted and movement of the gyro will take place about the axis *E, E*, the top of ring *C* and axle *B* moving toward the left. Movement of the gyro is thus seen to take place at right angles to the impressed force. This movement normal to the impressed force is called "precession."

Throughout the study of any gyroscopic apparatus it must be remembered that movement of the gyroscope does not take place in the direction of the impressed force, but that this tendency to move is transferred 90 degrees in the direction of rotation before it is manifested as motion.

Nothing but force caused by angular motion is resisted or causes precession; this angular motion may be about an axis within the gyro or remote from it, but must be angular motion. If linear motion be impressed, no gyroscopic reaction will result, even though the force so impressed be of large magnitude. As angular motion approaches linear motion,—*i.e.*, as its radius of action is increased,—the less will be its gyroscopic effect.

If the precessional ring *C*, Fig. 1, be clamped to the ring *D* so that precession is not allowed, then forces impressed on the ring *D* will not be resisted, even though they be due to angular motion, thus showing that precession must be allowed or the gyroscope will not have the property of resisting forces impressed upon it. It is for this reason that fly-wheels and turbine wheels have no real gyroscopic effect, precession being suppressed by the bearings in which the shaft is held.

All these reactions are due to manifestations of the laws of inertia. The relations between them are expressed by the following equation:

$$M = \frac{WK^2N\omega}{307}$$

M = The gyroscopic moment in pound feet.
W = Weight of the spinning mass.
K^2 = Radius of gyration.
N = Speed of the spinning mass in revolutions per minute.
ω = Velocity of precession, or angular velocity of tilt of the mass about any axis normal to the spinning axis in units of angular velocity or radians per second.

The relation of the various elements of the phenomenon,—namely, (1) direction of spin of rotating the body, (2) the direction of the impressed force, and (3) the direction of the resulting precession,—may be best remembered by comparing with some known and easily recognizable phenomenon. In all probability the child's hoop gives the best clue to these relations. When as youngsters we rolled the hoop we supposed that we were steering it when we beat the hoop at its top upon one side or the other; the facts are we were not steering the hoop at all, but we were impressing a stress upon the hoop, about a horizontal axis, and true gyroscopic action turned the hoop about the vertical axis and changed its direction, thus doing the steering, although we were entirely ignorant of this fact. But it is through this fact that the toy gives us the clue we seek, inasmuch as it involves no feat of memory to correlate the three elements: first, the direction of its rotation cannot be questioned when we are following the hoop; second, there can be no question as to which side of the hoop at the top we beat with the stick which we hold in our hand as we run along back of the hoop or beside it; and, third, there is no question which way the hoop turns when it is so struck. When we beat the top over to the right, precession turns the front of the hoop to the right, and when we beat the top to the left, precession turns the forward point of the hoop to the left. And so here we have a very simple method of remembering this phenomenon, involving all its three elements in their true correlation. The force we impressed about the horizontal axis of the hoop was transferred 90 degrees in the direction of rotation and there manifested as the motion which turned the hoop about its vertical axis.

Among the first attempts at engineering applications of the gyroscope, we find many efforts which have as their object the stabilizing of unstable bodies. The most important of these efforts have been directed toward stabilizing ships at sea. A ship is in effect a pendulum, and is for that reason subject to oscillation when acted upon by the force of waves, which cause it to roll and pitch in the manner with which we are all familiar.

German naval architects have damped the oscillations of this ship-pendulum by interposing on it a second pendulum in the form of so-called anti-rolling tanks. Many of us remember, from our experiences in the physical laboratory, that if we interpose a small pendulum on the arm of a large pendulum, the small pendulum will act in such manner as to damp the oscillations of the large pendulum, but only when acting in exact resonance with it and lagging 90 degrees in phase. This is exactly the principle of the anti-rolling tanks. The water in these tanks acts as a secondary pendulum which is calculated to oscillate in resonance with the ship but opposed to it in phase. From experiments in the physical laboratory, however, we know that considerable movement of the large pendulum must be set up before the small pendulum begins its oscillations or has any effect, and that if the period of the large pendulum be changed, or if the impulses which cause it to oscillate be changed, the small pendulum must stop and start over again. Briefly, this has been the trouble with the anti-rolling tanks. They have been at best a means for fractional damping of the roll only, and even this damping has been greatly handicapped by the fact that the impulses given the ship by the sea are totally irregular.

The most prominent workers in the field have been Sir Phillip Watt, Professor Biles, and the elder Freud in England, and, in Germany, Herr Frahm. The prominent scientist, Dr. Schlick, made several attempts to use part of the phenomenon of the gyroscope for stabilizing ships. A pendulous gyro was suspended in a ship with freedom of movement about its axis of rotation, which was vertical, and about its axis of precession, which was athwartship. This is called the "passive" type of gyro, and its application is beset with the same difficulties as the anti-rolling tanks; that is, a considerable movement of the ship must set in before the gyro has any effect.

Most of the advantages which would come to the maritime world by using a device for stabilizing ships are quite obvious. Briefly, they may be summarized as follows:

ADVANTAGES COMMON TO ALL SEAGOING SHIPS.

(*A*) Saving in power and consequent saving in fuel owing to the ability to maintain the shortest course between two points in bad weather, inasmuch as the ship will be in no danger from excessive rolling even when steaming in the trough of the sea.

(*B*) Saving in power and consequent saving in fuel owing to the fact that the wetted surface is not increased by wallowing, inasmuch as the vessel is always held on an even keel.

(*C*) Saving in power and consequent saving in fuel by elimination of rolling against the relatively stiff water when under way. This increase in the power required to drive a vessel which is rolling is due to what is known as the keel or form line impingement. It is illustrated by the far shorter extinction curve of the roll of the vessel when steaming than when not under way.

(*D*) Saving in power and consequent saving in fuel by reducing the yawing and tendency to follow a sinuous course.

(*E*) Saving in fuel and weight by the elimination of bilge keels.

(*F*) Making small ships as comfortable for passengers as large ships, while at the same time being able to prevent the largest from rolling.

(*G*) Eliminating stresses in the structure of the ship and the stresses in the accessories and auxiliaries contained within the ship, which are caused by excessive rolling.

(*H*) Preventing deterioration in cargo caused by excessive rolling. This would particularly apply to ships carrying live stock as cargo.

(*I*) Ability to roll the ship artificially for the purpose of freeing from or rolling off sand or mud banks by opening the contacting crevices and gradually liquefying the encumbent mass.

(*J*) Making a ship more seaworthy by preventing the shipping of seas due to rolling.

(*K*) Vastly increasing the efficiency, certainty, and range of usefulness of ice-breakers,—in fact, opening up a whole new field of operations for this important class of ship.

ADVANTAGES APPLYING ESPECIALLY TO MEN-OF-WAR.

(*A*) Decreasing the amount of underwater armor, which it is necessary to place on men-of-war at present in order to protect that portion of the hull which might be exposed to the enemy by rolling.

(*B*) Steady gun platform.

(*C*) Ability to go into action in any state of sea or upon any course in rough weather.

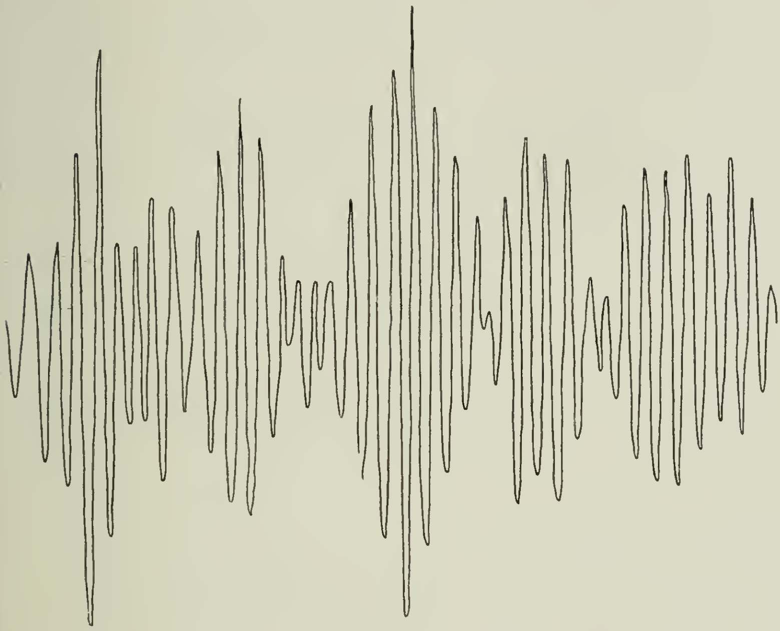
(*D*) Improving the condition of men and officers by eliminating the fatiguing and other effects of incessant and constant rolling.

(*E*) Ability to roll the ship artificially to standard angles as desired, in competitive target practice.

Very early in the work of stabilizing ships Sir John I. Thornycroft gave it as his opinion that ships could never be stabilized by means of the so-called "secondary resonance" phenomenon of the anti-rolling tanks, inasmuch as any device for efficiently quenching roll must deal with each impulse from the sea as it arises. To accomplish this he designed an anti-rolling pendulum hydraulically controlled to shift the centre of gravity of the ship so as to counteract each tendency to roll as it occurred. This device worked perfectly up to the breaking-down point of the couple so established.

A characteristic roll curve such as that shown in Fig. 2 will show that the roll is due to an accession of small impulses from the sea, and, if the ship is to be effectually stabilized, each of these small impulses must be counteracted as they occur.

FIG. 2.



Characteristic roll curve.

This is the principle on which the active type of gyro operates. In the application made on the U. S. S. *Worden* the gyros are mounted with their axes horizontal and normally athwartship and with their precession rings pivoted about the vertical axis. Movements about the vertical axis are controlled by an engine called the precession engine (see Fig. 9); this engine is in turn controlled in any one of several ways, for instance, by a small gyroscopic pendulum which maintains a fixed base line. A tendency to roll, of even so small an amount as 1/10 of a degree, is immediately felt by gyro pendulum, which accordingly controls the precession engine and causes it to move the gyros in such a manner as to deliver an impulse to the ship about its longitudinal axis which will exactly counteract the tendency to roll. This efficiently prevents any motion, and, as the ship is kept on an even keel, very little power is required to accomplish this. It efficiently performs the requirements set down by Sir John I. Thornycroft when he says that "the perfect stabilizer must act against the forces which are acting on the ship in such a way as to always resist the effect of the sea in producing motion."

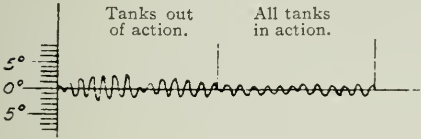
Fig. 7 is a photograph of one of the *Worden* gyros, showing the wheel casing, the induction motor (lower left) which spins the wheel through a friction drive, the vertical precession ring, and the self-oiling bearings.

COMPARISON—DAMPING TANKS AND EQUIVALENT GYRO STABILIZING PLANT, S. S. ASHTABULA.

Period of roll	Notes	Weights in metric tons			Percentage of displacement	Space required		Capacity for rolling ships
		Water	Tanks	Total				
				TANKS.				
						Cu.mtrs.	*Cu. ft.*	
6 Sec.......	Two tanks 60 feet and 40 feet long	784	95	897	19.8	960	33,180	None
6.6 Sec......	Two tanks 40 feet and 20 feet long	490	65	555	12.4	626	21,600	None
				COMPLETE GYRO EQUIPMENT.				
Any period..	One plant........	0	0	51	1.1	64	2,200	Through an arc of 8° to 10°

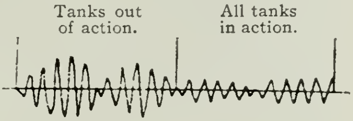
The gyro constitutes an ideal apparatus for this work, inasmuch as it is perfectly safe. It is unnecessary to run the wheel at any but comparatively low stresses. In fact, the stresses present can be brought below those used in hull practice. The comparatively slow motion of the wheel is very inexpensive to develop and maintain, representing only a small fraction of the power required to propel bilge keels; and this power, small as it is, is only required when the necessity for stabilizing arises, and then only in proportion to the seas running at the time; whereas the power required to drive the bilge keels is a constant drag in all weathers. The power for controlling precession is trifling,—only sufficient to absolutely control and limit the precession movements at all times. This arises from the fact that in stabilizing the constant tendency of the ship is to do precession-wise work upon the gyro. This is fully borne out in practice, as it is found that the power required for the precession engine is almost *nil*, it being sufficient to control the implacement of the positive and negative energizations delivered to the ship. The gyroscope is ideal in another sense, for with it we have the weight of Thornycroft greatly augmented as to mass moment by the simple fact that it is in rotation which constitutes a multiplier of tremendous magnitude, even though the actual rotative speed is comparatively low.

FIG. 3.



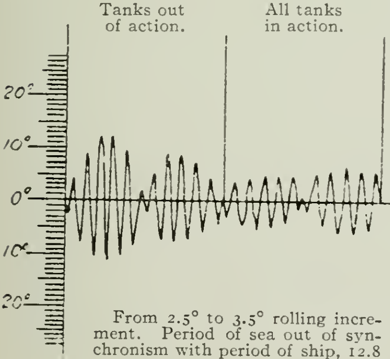
From 6° to 9° rolling increment. Period of sea out of synchronism with period of ship, 13.1 per cent.

FIG. 4.



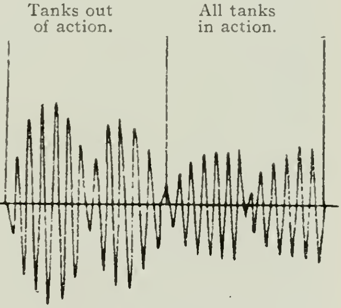
From 1¼° to 1¾° rolling increment. Period of sea out of synchronism with period of ship, about 12 to 14 per cent.

FIG. 5.



From 2.5° to 3.5° rolling increment. Period of sea out of synchronism with period of ship, 12.8 per cent.

FIG. 6.



From 4° to 5° rolling increment. Period of sea out of synchronism with period of ship, 9¼ per cent.

That Thornycroft was correct in his line of attack on this problem has now received emphatic confirmation. The effectiveness and mass moment of his weight have been mightily augmented on one hand, while on the other its gravity load upon the ship has been decreased and at the same time the position of its centre of gravity is never shifted. If all these things had originally been in the hands of our distinguished contemporary it is impossible to predict the very great advance that the art of stabilizing ships would by this time have achieved, as only last year he stated: "I came to the conclusion twenty years ago that it was possible to make ships perfectly steady."

In connection with dealing with each individual increment, let us for a moment again refer to Fig. 2. As we trace the envelope of these curves in their rise and fall we note near the centre line where the phase is usually shifted there is always the first impulse of a new cycle, the one which starts the cycle. Now if no cycle of rolling ensued we would have simply a succession of these beginnings, which would naturally be of various signs and magnitudes. These are more numerous in a vigorous, choppy sea, where, as stated, the cycles themselves are shorter and the individuals which shift the periods appear oftener. Now if each of these beginnings could be efficiently suppressed neither the cycles nor the individual rolling constituting these cycles would ever come into evidence, and it is just this suppression that we are enabled to effect by the active type of gyro.

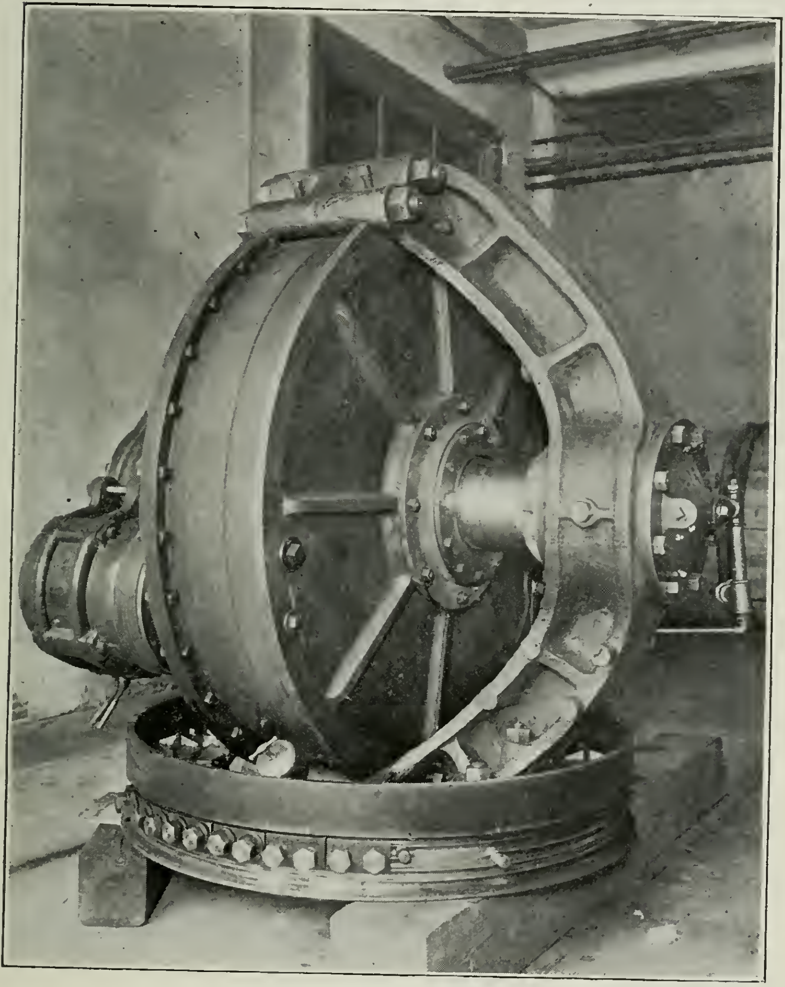
Calculations dealing with known tank equipment well illustrate the powers of the active gyro stabilizer. Let us take the case of Figs. 3 to 6, where only a comparatively small fraction of the roll was dampened, owing to the sea being out of synchronism even by but a slight percentage. The active equipment, as we have seen, is different. It most promptly deals with each momentary energization and "has no memory"; it cares not when nor from what direction the previous stress attack the ship.

The surprisingly small magnitude of the whole gyro equipment is due largely to its unique method of operation; that is, it makes up in activity and promptness what it may seem to lack in size and weight.

This small space is practically independent of location. It need not occupy the most valuable amidships space nor extend entirely across the ship at a point of greatest beam. It may even be divided up in two smaller spaces and be stowed away at any point selected by the designer. In this way the small space required may be that which is least valuable in the whole ship.

Again, the gyroscopic plant is entirely independent of the height component of location, as it is found to operate equally well in the lowest part of the ship and is entirely independent of symmetry as to disposition in relation to the ship's centre of oscillation. The gyro precessions being under individual control, each is rendered effective with full force. This persistent and incessant action always in the right direction, not waiting for the

FIG. 7.



One of the active gyros of the *Worden.*

period, but working more rapidly than the period, constitutes another explanation of the smallness of the necessary plant. In modern ships of low metacentric height it is found that the active gyro equipment will represent only a fraction of one per cent. of the displacement.

Another great advantage of the active type of stabilizing gyro, and the advantage that led to the design of this gyro for the *Ashtabula,* arises from the fact that it can be used to produce roll and so cause a ship to break through the ice or enable it to roll off a sand or mud bank.

The gyro employed only requires to be run at one-third or one-half speed for the production of all the rolling that could ever be required by the *Ashtabula* in breaking through the heaviest ice. This is owing to its incessant action developing its full force in proper direction and with the proper emplacement upon each half period. Very heavy rolling can easily be produced and maintained. The action under these conditions is far simpler than in preventing roll, inasmuch as the reaction of the ship, after rolling, is found to react back to the gyro sufficiently to automatically control its precessional movements.

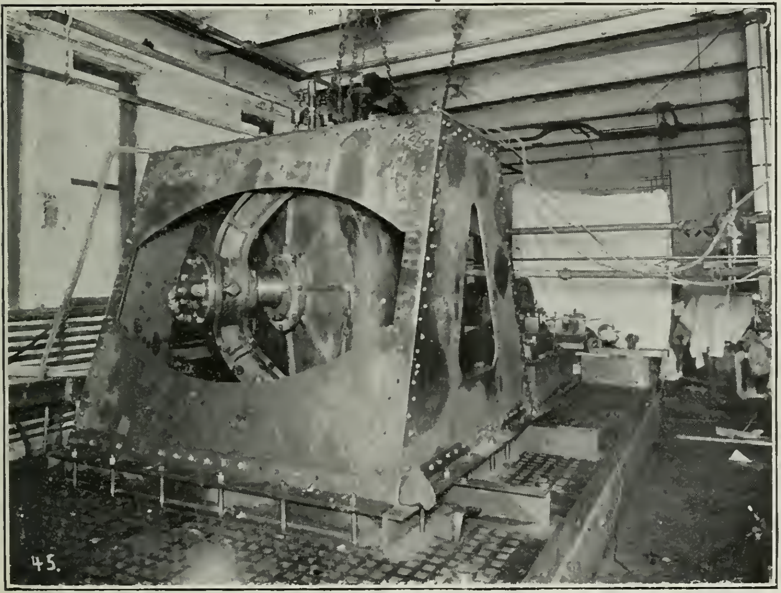
The discussion of stabilized ships reminds me of an amusing incident which occurred at the navy yard in Washington during experiments preliminary to installing a plant on the U. S. S. *Worden.* These experiments were being made with models to simulate a ship, and it had been shown that the principle of the active type of gyro would enable us to do exactly what we had claimed we could do. After the experiments were over an old bluejacket who had been helping us asked me what it was all about, and I told him that the experiments just completed proved that we could prevent ships from rolling. He turned to me and in a very disgusted manner told me that if I had ever been to sea I would know that it was foolish to try to do anything of the sort. "Why," he said, "when you get out there in the middle of the ocean what have you got to hang on to to hold her?" He was right. You do have to have something to "hang on to." And that something must be very powerful. In the case of the stabilizing gyros it is the tremendously augmented inertia of the rotating mass.

I recently had the honor of presenting a paper before the Society of Naval Architects and Marine Engineers, and after this paper had been read I was told by the well-known engineer, Mr. W. L. R. Emmet, that the performance of the active gyros in preventing roll of ships described in my paper reminded him of those lines of Kipling:

> I'm the prophet of the utterly absurd,
>   Of the patently impossible and vain;
> And when the thing that couldn't has occurred,
>   Give me time to change my leg and go again.

So far from being "patently impossible and vain," the results thus far actually achieved have been obtained by machinery which though unusual is in fact of the simplest character. The installation was found to perform its function so naturally and with such apparent ease as to leave little to be desired as to method. This I believe to be parallel with what has often occurred in the past, that the problem that seems the most insurmountable, like Achilles, has a vulnerable point, and in fact the "thing that couldn't" has been found very simple of solution after it has been fully analyzed and when attacked from the proper angle.

FIG. 8.

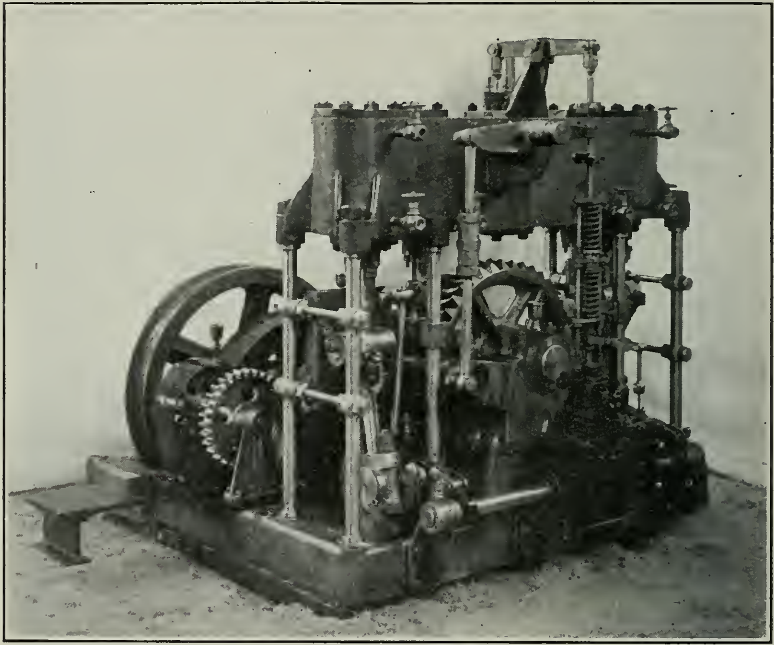


One of the active gyros in the tower during shore trials.

Fig. 8 shows one of the active type of gyros preliminary to its installation on the ship. It was tested in the position shown in the Electrical Laboratory at the Navy Yard in New York. During this test it was found that the precession of the gyro would easily lift the heavy plate on which it was bolted. The weight of this plate and load was approximately 67,000 pounds.

Fig. 9 shows the precession engine.

FIG 9.



The precession engine.

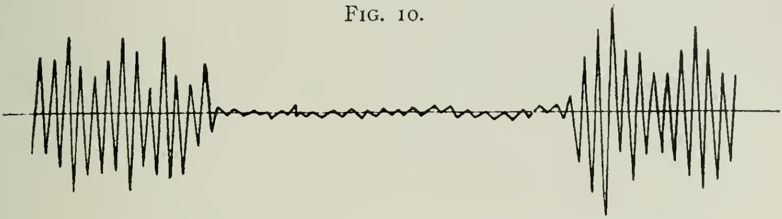
Fig. 10 shows a rough stabilizing curve, the ends showing the sea running at the time.

Fig. 11 is a view of the middle portion of the *Worden* from the starboard side, and shows what a comparatively small amount of space is occupied by the stabilizing apparatus.

Fig. 12 shows periodic motion of a ship and the dying-down curve in still water.

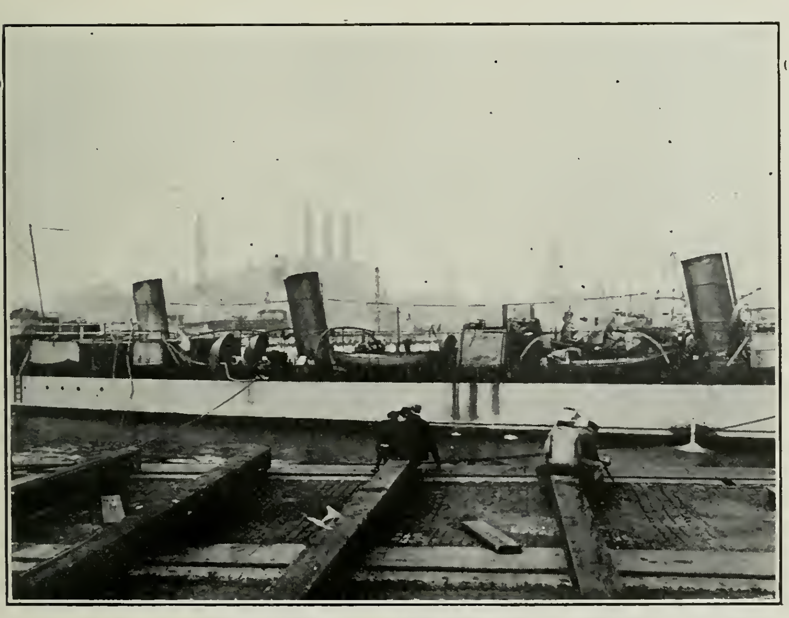
Fig. 13, taken from one to two minutes later, shows the dying-down curve when steaming at 15 knots. Both of these curves were taken in smooth water. Great interest centres in the striking difference between these two curves. This comes from the fact that here, for the first time in the history of navigation, and by the use of the active type of gyroscope, opportunity has been afforded for rolling a ship at will under practically all possible conditions of sea and headway; and here is presented a striking instance of the unexpectedly great effect upon the form-line resistance of the ship due to the relatively stiffer water which is present when steaming as compared with that when

FIG. 10.



A rough stabilizing curve, the ends showing the sea running at the time.

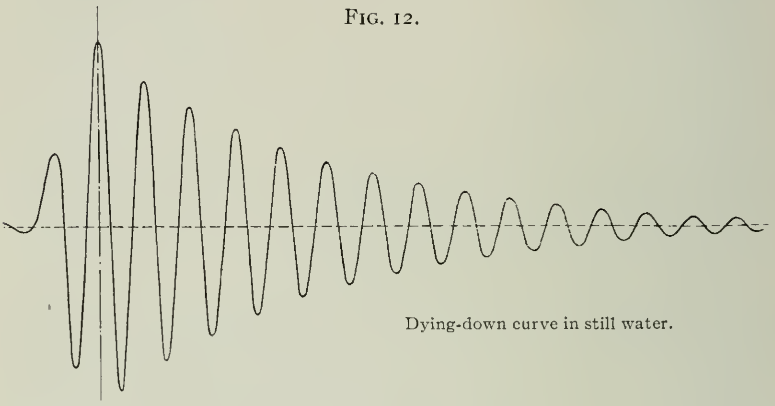
FIG. 11.



U. S. S. *Worden*, starboard side, middle section of ship only, showing gyro installation.

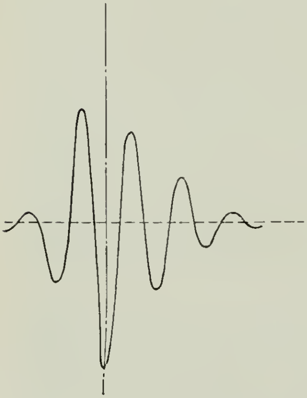
lying to, other conditions remaining the same. The interpretation of these results shows the relatively large amount of power expended due to form-line impingement resistance when steaming. Thus, from these curves may be calculated the exact amount of retardation or slowing-down effect which would be encountered by the ship when rolling as compared with the same ship when not rolling, while steaming at practically any rate.

FIG. 12.



Dying-down curve in still water.

FIG. 13.



Dying-down curve when steaming at 15 knots.

The results of these investigations indicate that quite a large amount of power is expended in driving a vessel at a given speed that rolls over and above one that does not roll.

Through the important work to which only brief reference has here been possible knowledge of the performance of the stabilizing gyro under service conditions has been accumulated.

This is now such as to enable us to calculate with all necessary accuracy the weight and space occupied in connection with practically any plant either for stabilizing or breaking ice; also to predict with certainty what the result will be, the amount of power required, and also to prescribe with fair degree of accuracy about what will be the stabilizing or rolling factor upon any given ship with the new active gyros fitted.

So far as appearance and construction are concerned, it is a far cry from the gyro stabilizer to the gyro compass, although both are founded on the same fundamental phenomenon,—that is, rotation, inertia, and precession.

As necessity is the mother of invention, so the reverse would also seem true, each development in science and engineering necessitating the development of some device or devices to increase the efficiency of the prime development. The magnetic compass served its purpose when ships were made of wood, and the compass could be depended upon to indicate the position of the North approximately. The development of the steel ship, especially the steel man-of-war, has made necessary some compass free from magnetic influences, and the gyro-compass is the result of this necessity.

The use of the magnetic compass involves the application of two classes of errors: variation, or errors arising from forces extraneous to the ship; and deviation, or errors arising from forces within the ship. Both of these classes of errors constantly vary in a manner not capable of prediction.

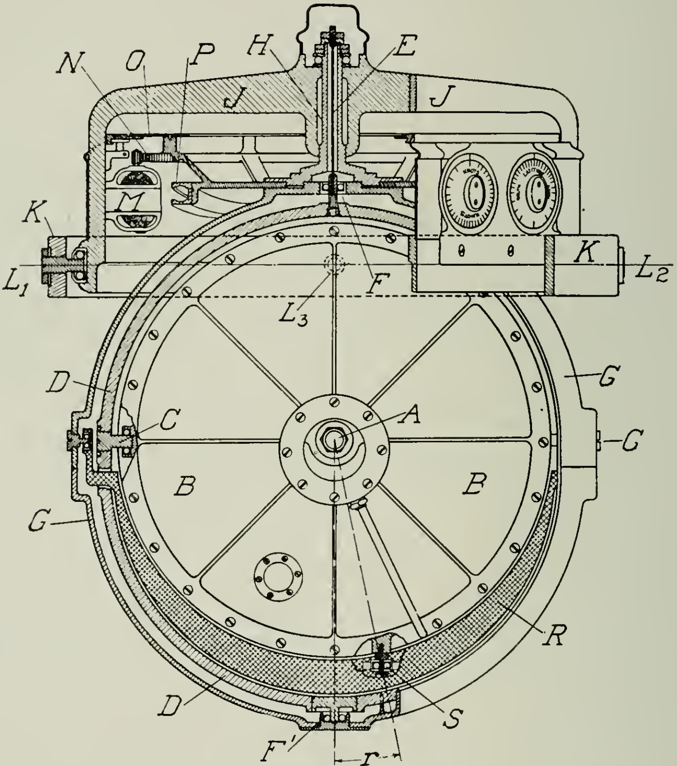
As the directive force of the magnetic needle is very weak, the compass tends to follow the ship's head instead of holding the meridian; the result is inaccuracy in steaming and observation of bearing.

All instruments used for men-of-war must be designed to contribute their part to the efficiency of the ship in battle. The compass in that case must be used behind armor, in which position the magnetic compass is of little or no value. In manœuvring in fleet and in navigating near the coast the use of the magnetic compass in getting bearings of the flagship or objects on shore makes it very inconvenient, as it involves the constant application of errors and transference of compass heading to pelorus, or dumb compass, from which observations are taken.

In the present day of the steel ship and submarine the use of the magnetic compass, dependent as it is on a weak and variable force, is almost as much of an approximation as the means used hundreds of years ago in directing ships by observations of the sun, moon, and stars.

The gyro-compass indicates the direction of true or geographical North by reason of a force which is absolutely changeless and undeviating,—that is, the force of the earth's rotation. An understanding of its operation will be facilitated by referring to Fig. 14, which is an elementary cross-section through the East-West plane of the master compass. The wheel rotates on an axis *A* within the casing *B*. This casing *B* is in turn pivoted upon a horizontal axis *C*—*C*, these pivots being fixed in the vertical ring *D*. Ball bearings are used both at *A* and *C*, and

FIG. 14.

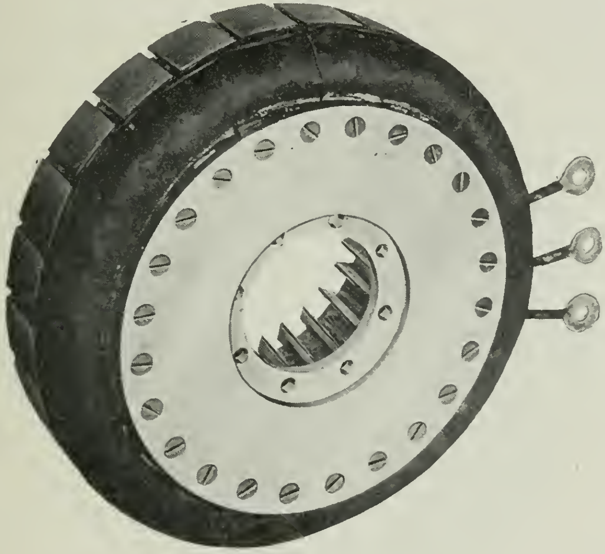


Cross-section of master compass.

the wheel runs in a vacuum which is maintained in the casing *B*. The vertical ring *D* is suspended by a stranded wire *E*, and is guided about the vertical axis by the bearings *F*—*F*.

The gyro, its casing, and the vertical ring constitute what is known as the sensitive element. Surrounding this sensitive element is the ring *G*, to which are secured the compass card and the stem *H*, and these parts are made to follow all movements of the sensitive element about the vertical axis. This is accomplished by the means of an electric follow-up system actuating a small motor *M*. The gyro, or sensitive element, serves only as the directive part of the instrument, and forms no part in actually driving the compass card or attachments thereof; the actual driving force being provided by the small motor *M*.

FIG. 15.

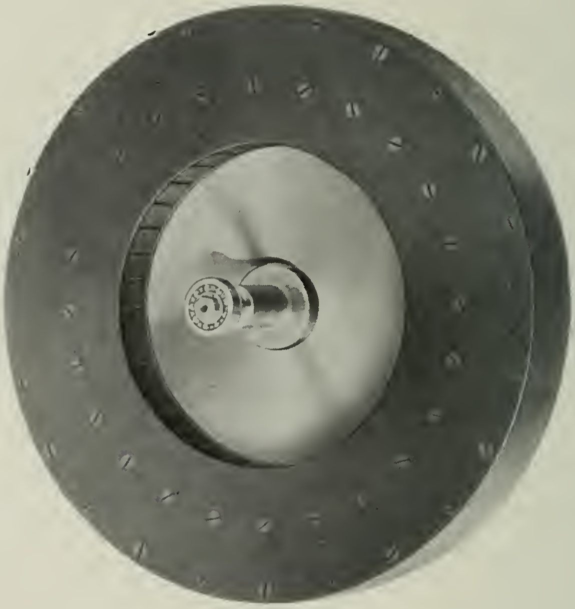


Stator.

It will be clear that the outer ring *G* is at all times rigidly held in position with reference to the supporting frame *J*, although it is at the same time free to move around the vertical axis, and stands in practically constant relation to the gyro wheel or sensitive element. This ring, therefore, serves as a base to which the restraining element, or pendulum *R*, is attached by means of the pivots shown. This restraining element is attached to the gyro casing at the point *S*.

A rapidly rotating wheel tends to maintain its plane of rotation relative to space, and if the axis of this wheel is not on the North-South meridian the earth in turning on its axis tends to "rotate from under" the gyro wheel and the axis of this wheel inclines with relation to the horizontal. This inclination takes place against the weight of the restraining pendulum *R*, which impresses a force about both the horizontal and vertical axes.

FIG. 16

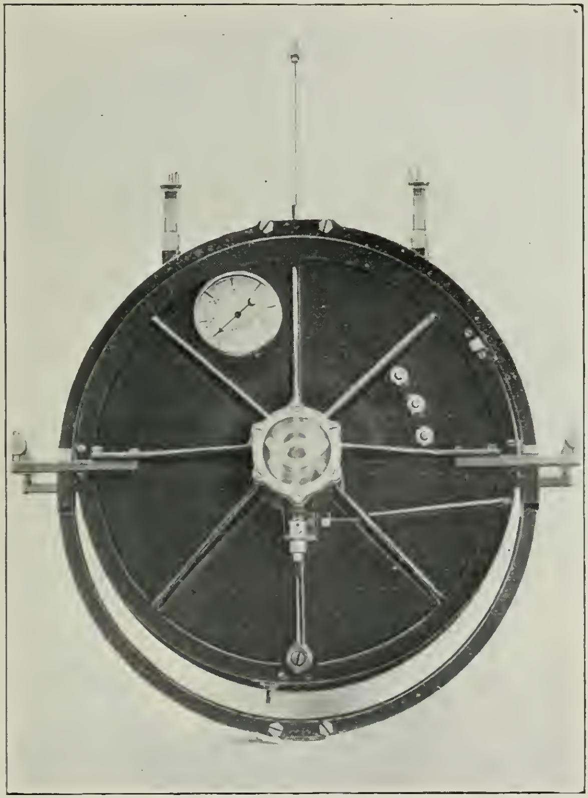


Rotor.

The force about the horizontal axis institutes a precession toward the meridian, while the force about the vertical axis damps this precession to bring the axis of the gyro to rest in a horizontal position when on the meridian, in which case the plane of rotation of the wheel is coincident with that of the earth, and the earth, therefore, no longer tends to rotate out from under the gyro wheel.

The directive force, while very large compared to that of the magnetic needle, is, nevertheless, small, and the gyro-compass must be made with perfect freedom about the vertical axis. Since the top of the suspension wire is constantly moving to follow the bottom, the gyro is suspended from what is in effect a torsionless wire and perfect freedom is obtained about the vertical axis. This method of suspension has made possible an extremely accurate instrument which is at the same time very durable and substantial.

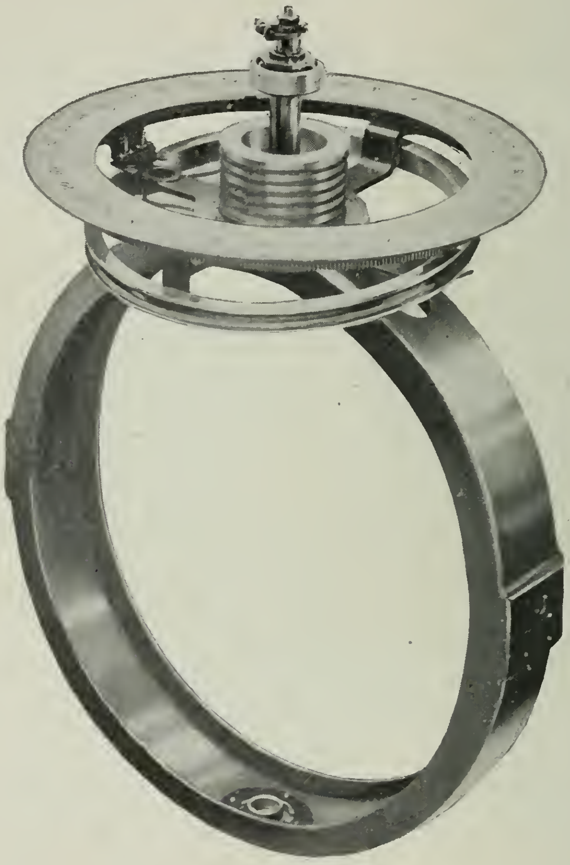
FIG. 17.



Wheel casing and vertical supporting ring.

To be rigidly exact, I must confess that the gyro does not take up its position exactly in the North and South meridian, but deviates from it by a known amount, the magnitude of which depends upon three variable factors,—namely, the latitude, speed, and course of the ship on which it is mounted. The northerly and southerly components of speed act to change the apparent direction of the earth's rotation, and the effect of this speed varies with the latitude, inasmuch as the linear speed of any point on the earth's surface varies with the latitude. Another latitude correction is introduced by the fact that the compass lags behind the meridian by an amount varying with the latitude; this lag being due to the fact that a certain amount of force is impressed about the vertical axis by the restraining pendulum for

FIG. 18.

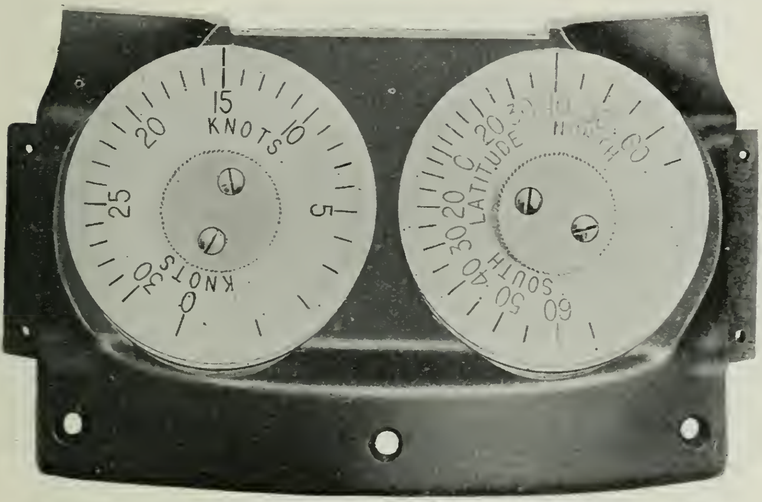


Phantom card, azimuth gear, and cam for automatic correction mechanism preventing oscillations. The total correction is expressed by the equation:

$$D = (H \cos K \div \cos L) \pm \operatorname{Tan} L. \quad \text{Where } H = \text{speed};$$
$$K = \text{course, and } L = \text{latitude.}$$

An automatic correction device is attached to the compass card which, when set for approximate speed and latitude, applies all of these corrections. This device consists of a number of cams so laid out that when the dials are set for ships' approximate speed and latitude the various factors are combined and the correction is automatically applied.

Fig. 19.

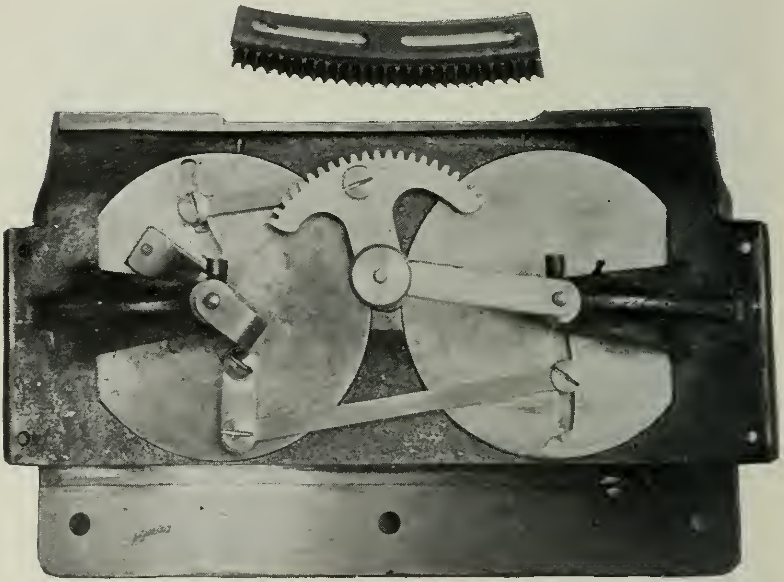


Automatic correction dials, setting 15 knots, 40° North latitude.

The gyro-compass can, of course, be placed well below the water line and behind the heaviest armor of the ship. Its indications are repeated to any desired station on the ship by means of an auxiliary system operating the cards of so-called "repeater compasses." This system consists of a transmitter on the master compass which controls the poles of a small motor in the repeater compass in such manner that the armature of this motor is turned by steps to follow the moving dial of the master compass. The armature of this small motor is geared to the repeater dial so that one revolution produces a 2 degree movement of the dial. The motor has six poles controlled in pairs, so that the armature stands between one pair, then half-way between that pair and the next, then between the next pair, and so on, having twelve resting positions in each revolution. The repeater dial, therefore, moves $^1/_6$ degree for every $^1/_6$ degree movement of the master compass dial, yielding a maximum error of $^1/_{12}$ degree.

The results accomplished by the gyro-compass in service have been of the greatest interest in bringing out many unexpected advantages. It provides an accurate means of navigating, and a means which is perfectly free from lag. This results in considerable saving in coal by increasing the accuracy with which the courses are run from point to point and by decreasing the amount of helm used, inasmuch as the helmsman has a compass without a lag and can keep the ship on the course by using a small amount of helm. Many of the navigators who have used the compass estimate that the saving in coal accomplished amounts to eight or ten thousand dollars during a year of ordinary service. Applied to battleships, the results accomplished

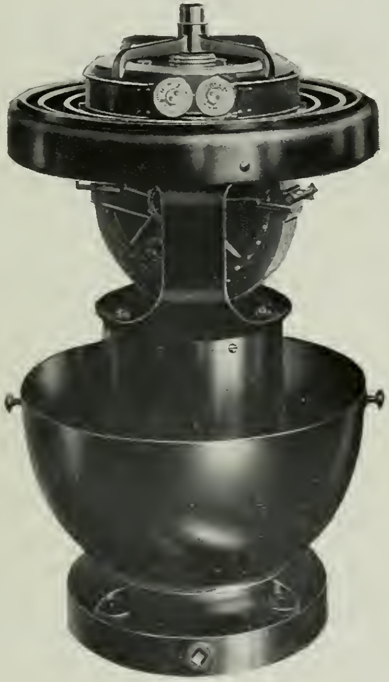
FIG. 20.



Back of correction device.

are of the greatest importance. The ship may be steered as well from an armored station as from an unarmored station. With the gyro-compass the helmsman can, therefore, be stationed in the steering engine-room, where he is well protected and where there is little chance for failure of connecting him with the steering engine mechanism. The commanding officer can then manœuvre the ship from the conning tower or other armored station by maintaining communication with the helmsman over the voice-tube or telephone. In formation in column, it is found that the position of ships can be maintained with far greater accuracy, as the small use of helm is conducive to the maintenance of constant speed of all ships. With the use of the magnetic compass the varying amounts of lag result in varying the amounts of helm used and in consequent variations of speed. This variation in speed makes it difficult to maintain the distance

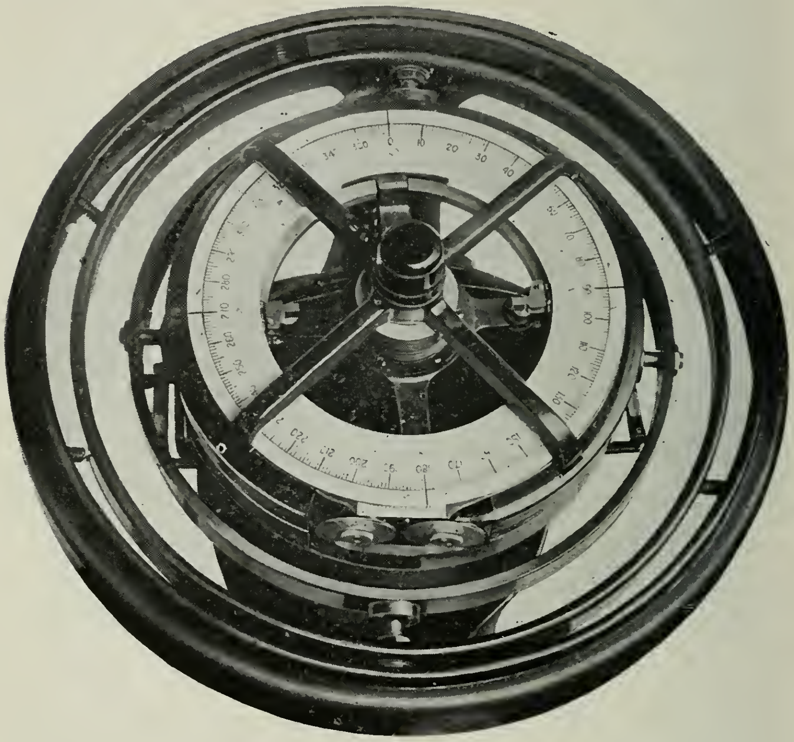
FIG. 21.



Master compass binnacle, lower part down.

between ships. In formation on line, or line of bearing, no possibilities exist for errors due to misapplication of the compass deviation or correction in closing or opening intervals by changing course toward or away from the flagship. The necessity for continuously applying deviation and setting the pelorus, or dumb compass, is avoided. A special type of bridge or conning tower repeater, designed to replace the old pelorus or dumb compass, makes it possible to get the true bearing of the flagship directly. This is of great advantage, also, in navigating near the coast, as true bearings of objects on shore may be obtained with great accuracy. The use of the gyro-compass on submarines is estimated to have increased their efficiency fully 50 per cent. by providing a means for steering an accurate course when submerged.

FIG. 22.

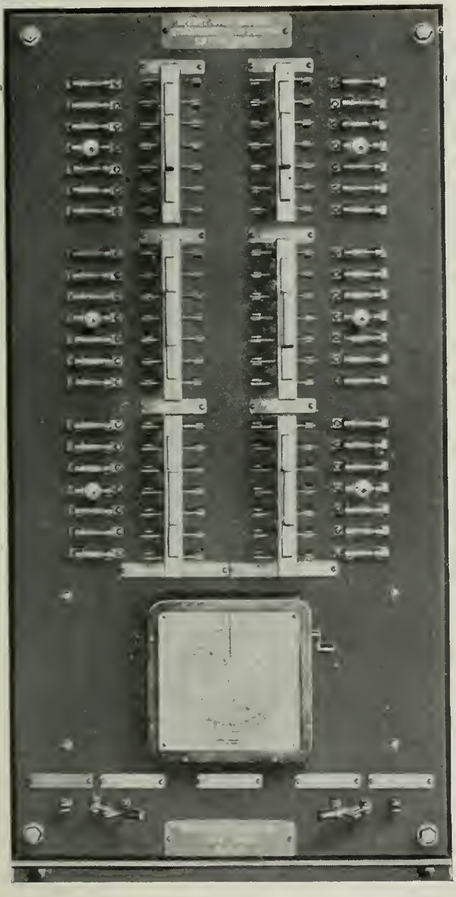


Master compass card from helmsman's position.

Fig. 15 is a photograph of the stator of the induction motor driving the gyro wheel. This stator is mounted on the inner side of the gyro casing shown in Fig. 14.

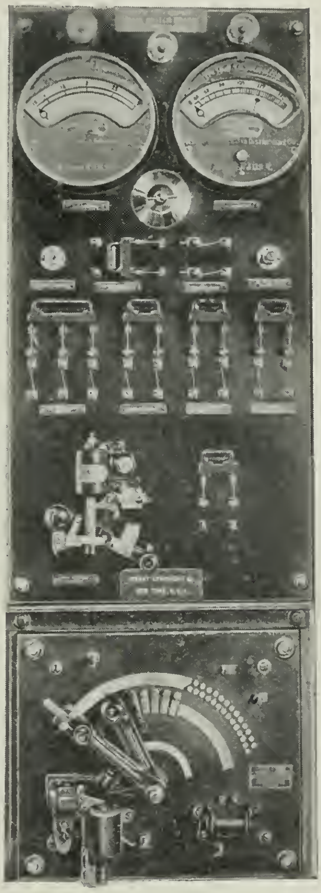
Fig. 16 is a photograph of the rotor, having inlaid on its inner periphery the short-circuited bars of the induction motor.

FIG. 23.



Synchronizing panel.

FIG. 24.



Main switchboard.

Fig. 17 is a photograph of the gyro mounted in the vertical cardan ring.

Fig. 18 is a photograph of the "phantom" ring which surrounds the sensitive element and is driven to follow it.

Fig. 19 is a photograph of the front view of the correction device.

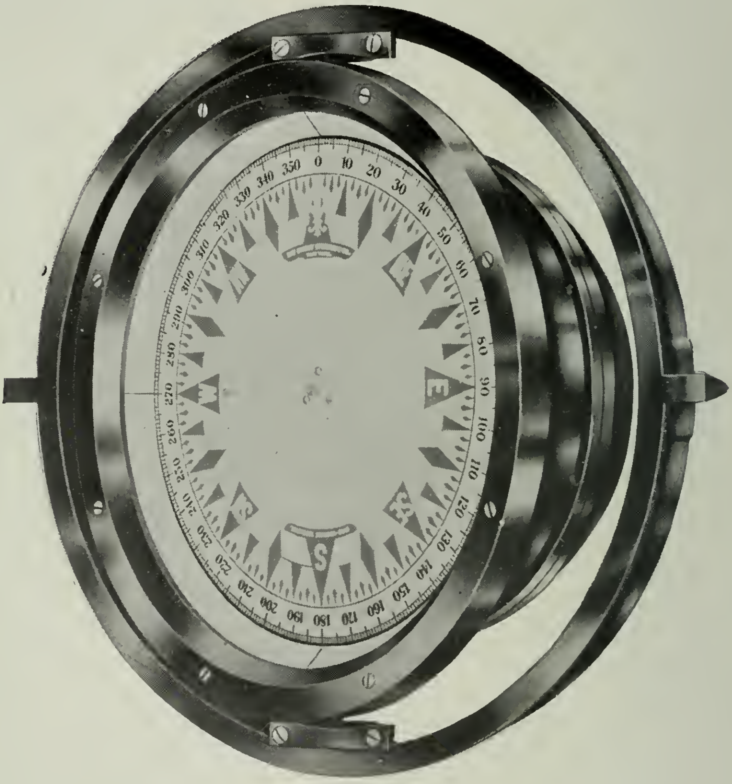
Fig. 20 is a back view of the correction device.

Fig. 21 is a view of the assembled gyro-compass.

Fig. 22 is a top view of the compass.

Figs. 23 and 24 are views of the switchboards.

FIG. 25.



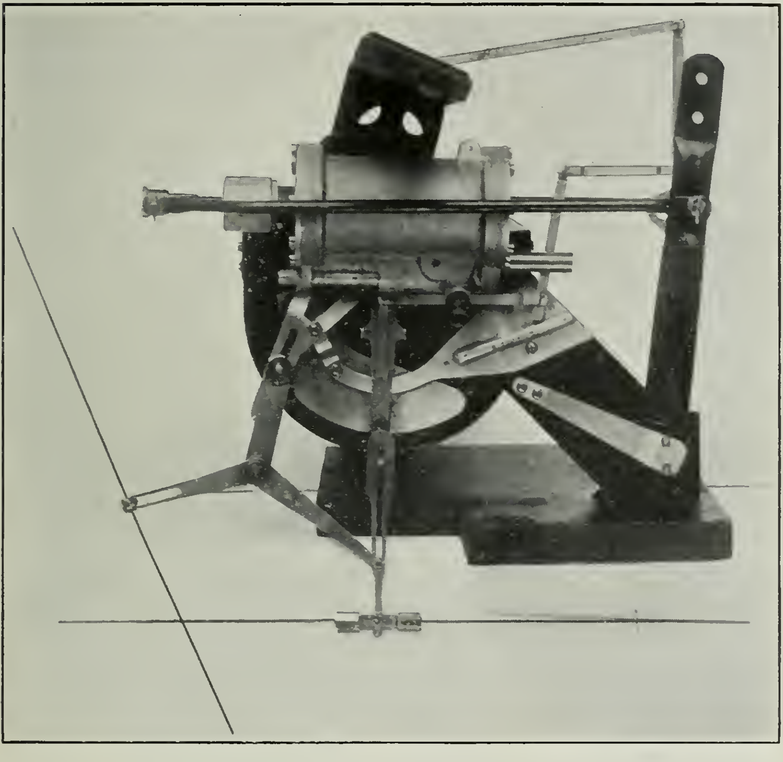
Repeating compass, binnacle type.

Fig. 25 is a view of the repeater, or auxiliary compass.

Perhaps the most interesting of all the apparatus which we have developed is the aëroplane stabilizer. Air is a very unstable medium, and the development of the heavier-than-air machine has shown us that the atmosphere is in a constant state of turmoil, rendering its navigation perilous. The aviator must work constantly to maintain the stability of the machine about all three axes. With the present machines very long flights are nearly beyond the endurance of the aviator, and even short flights are difficult when the weather is at all bad.

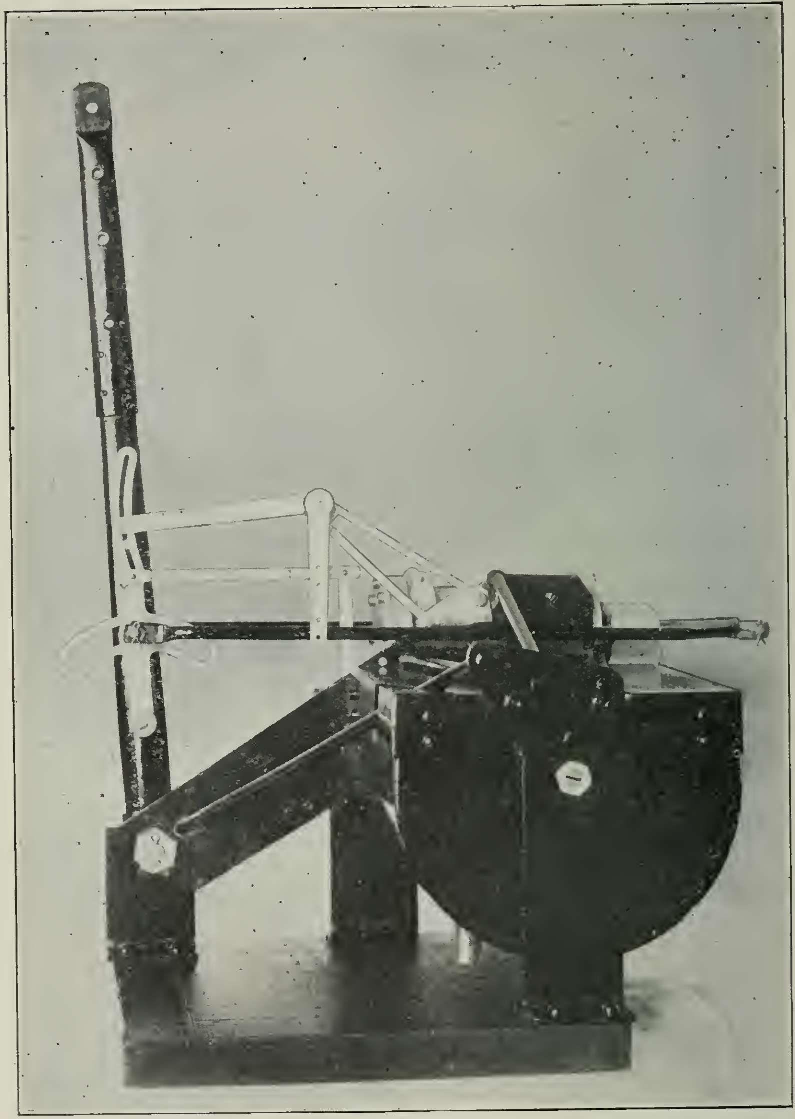
Each aëroplane stabilizing equipment comprises a combination of devices for maintaining longitudinal stability and a combination for maintaining lateral stability. The longitudinal stabilizer uses three directive factors for controlling the movements of a pilot valve, which in turn controls a compressed-air cylinder operating a piston attached to the horizontal rudders. The controlling factors are: first, the gyro which through the pilot valve operates the horizontal rudders against tendency to tip about the horizontal axis; second, an air platen which operates

Fig. 26.



The lateral stabilizer.

FIG. 27.



The longitudinal stabilizer.

the pilot valve to volplane the machine in case the speed drops below the critical speed necessary for sustaining the plane; third, a hand-setting device which permits the aviator to set the stabilizer for any inclination of climb or descent. The air platen further acts to adjust the throw of the levers so that when running at slow speeds a small tipping is counteracted by a suitable throw of the rudders. This is made necessary by the fact that the plane is, of course, more sensitive to inclinations of the rudders when running at high speed.

The lateral stabilizer serves as a directive factor, acting on the pilot valve to control the movements of the ailerons so that they operate to counteract against tipping laterally. When turning, the lateral stabilizer operates the control mechanism to bank the machine to an angle sufficient to prevent skidding.

The gyros of the aëroplane stabilizer are continuously spun by three-phase alternating current derived from a small generator driven from the shaft of the engine. This generator is designed to develop alternating current for driving the gyros, low-voltage direct current for exciting its own fields, and single-phase alternating current for use in connection with the radio set. The low-voltage direct current may also be used for ignition service of the engine.

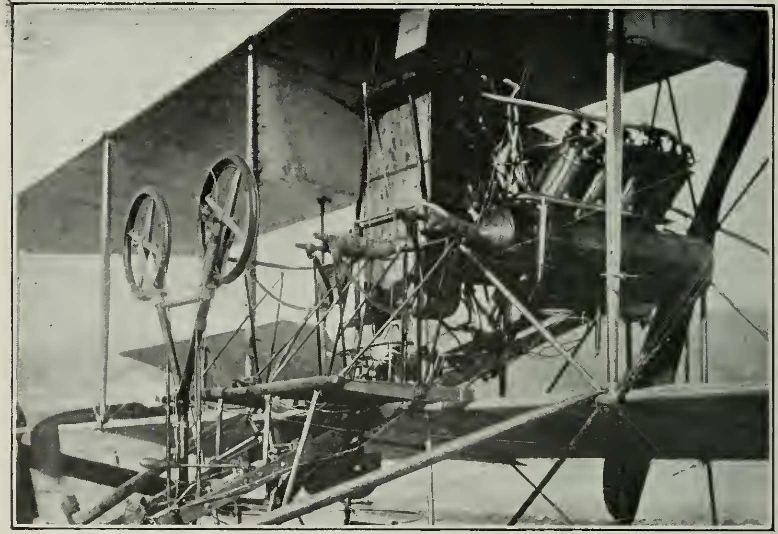
It is an interesting fact that the gyros connected to the generator circuit act as boosters to restore part of the energy given to them when a circuit to the wireless is closed; thus momentarily the wireless equipment is supplied not only by the generator but also the gyros acting as induction generators.

A valve connected to the compression space of one of the engine cylinders automatically stores compressed gas in a small accumulator tank, from which it is used to operate the pistons controlling the ailerons and rudders.

The same type of stabilizer may be used on any type of aëroplane, as the installation simply involves supporting it firmly on the machine and attaching the arm operated by the compressed-air piston to the wires or levers of the existing hand control. Both ends of the compressed-air pistons are provided with valves, all of which may be opened by releasing a thumb button attached to the steering wheel of the aëroplane. When these valves are opened the stabilizer continues to function, so far as the relation of all of its parts is concerned, but has no effect on the ailerons or rudders, as the piston is prevented from doing any work. This makes it possible for the aviator to instantly shift from hand control to automatic control.

The weights and dimensions of the various parts of the stabilizer are surprisingly small. The weight of the generator is about 25 pounds and it occupies a space of about six by six by ten inches. The lateral stabilizer weighs about 18 pounds and is small enough to be conveniently disposed at the back of the aviator's seat. The longitudinal stabilizer weighs about 17 pounds and is placed below the aviator's seat in such a position that he can see its operation at all times.

FIG. 28.



Aëroplane showing both stabilizers installed.

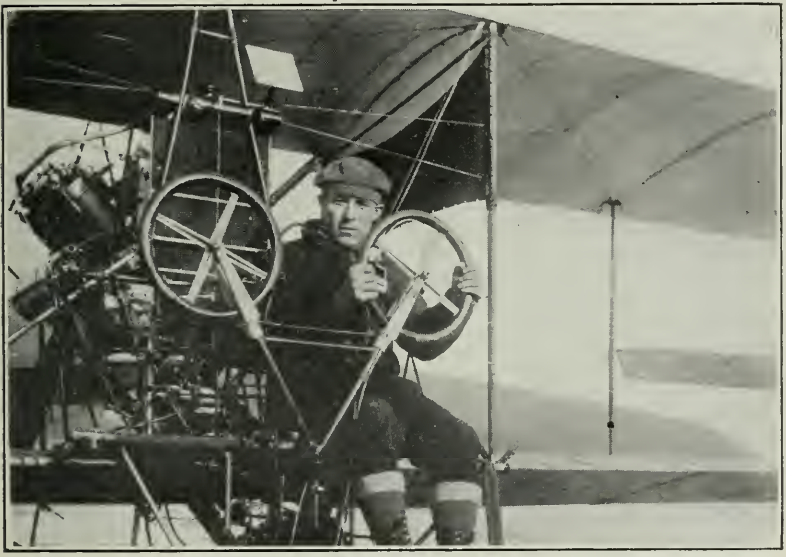
The automatic control of stability of the heavier-than-air machines will do much to decrease the growing list of fatalities, as it provides a means for acting simultaneously with the disturbing air currents, whereas the aviator must always wait until the effect has manifested itself before he applies the remedy, and then he very often misjudges the amount by which he should move his controls.

The automatic control of stability will be especially valuable to the military use of the aëroplane, as it will make it possible to fly in almost any condition of weather and will make long flights possible. In reconnaissance service only one man will be necessary, as the machine may be controlled automatically while the aviator makes sketches, records information obtained, or operates the radio set to communicate with his base.

Fig. 26 is a view of the lateral stabilizer.

Fig. 27 is a view of the longitudinal stabilizer.

FIG. 29.



Illustrating thumb button for cutting out automatic control.

Fig. 28 shows both stabilizers installed on the Curtiss hydroaëroplane.

Fig. 29 shows the thumb button by means of which the stabilizers may be cut in or out.

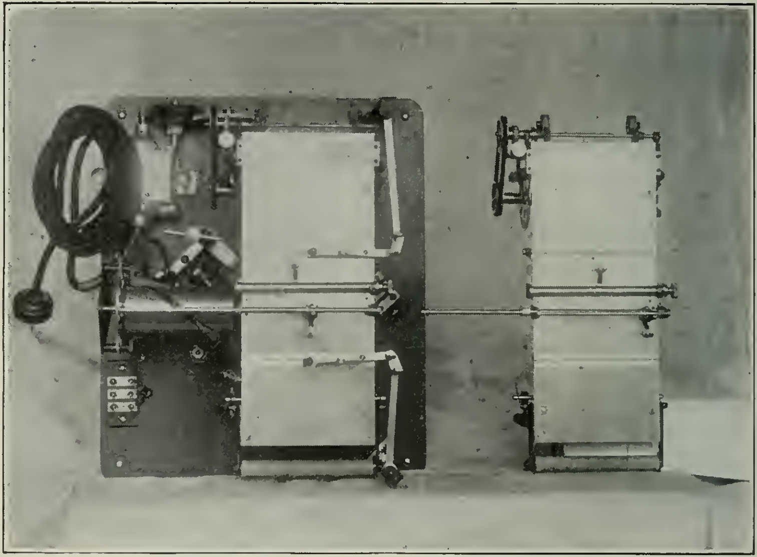
In conjunction with the U. S. S. *Worden* trials were used interesting apparatus for recording the roll and pitch of the ship. Pendulous gyros were used to maintain the athwartship and fore and aft axes, and these gyros operated pencil arms resting on a paper tape moved by clockwork. It was found that this mechanism was so sensitive to changes in the angle of roll and pitch of the vessel that it would indicate the roll caused by two men moving from one side of the ship to the other.

Fig. 30 is a top view of the roll and pitch recorder.

Fig. 31 is a side view of this instrument.

The artificial horizon is the most recent application of the gyroscope. Although the problem at first appeared somewhat complicated, later developments showed that a 12-inch circular mirror could be maintained in a horizontal position with perfect accuracy and by the use of a very simple combination of gyros. The artificial horizon as now constructed is portable and entirely self-contained. The mirror is levelled by hand. The double altitude of the sun or heavenly body is observed by measuring the angle between the body and its reflection; the mirror is then readjusted and the observation is repeated. If any error was introduced in the first observation by inclination of the mirror, this error will be equal and opposite in the second observation, and an average of the two observations, divided by 4, gives the exact altitude of the body. Errors are frequently introduced in navigation when measuring the altitude of a heavenly body

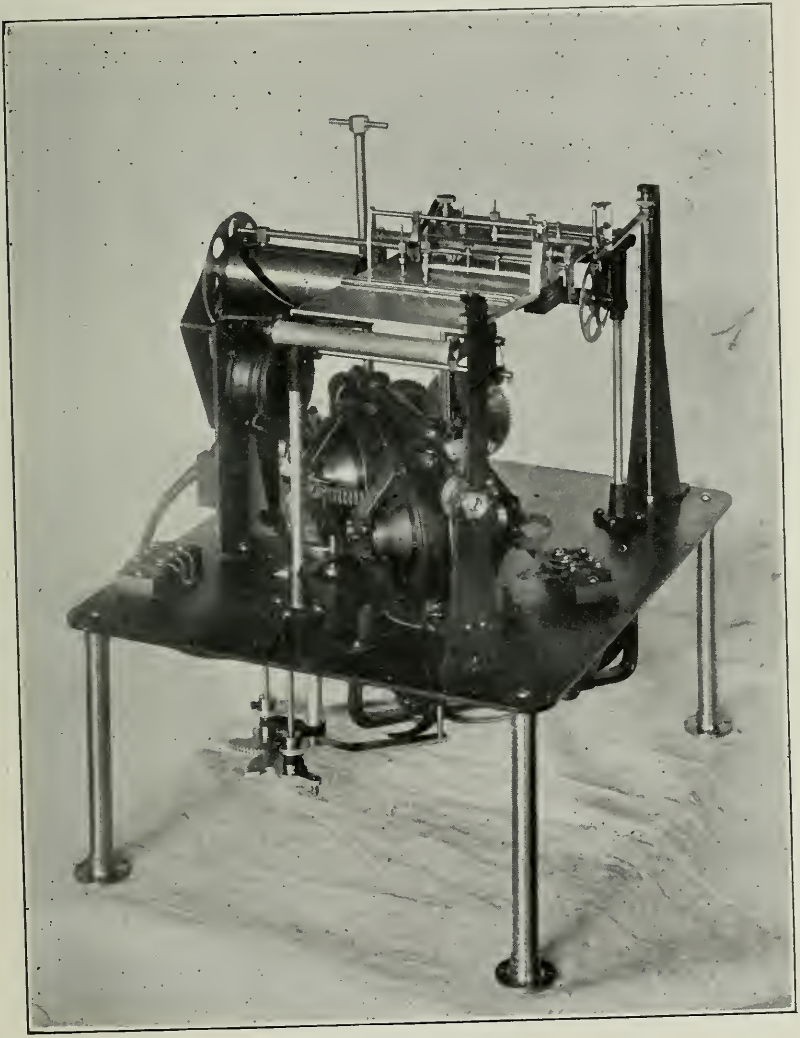
FIG. 30.



Top view of roll and pitch recorder and duplicate platten.

above a false horizon, caused by mist or by the mirage effect of the heat of the air on tropical seas. Very frequently observations of the sun or heavenly bodies could be taken were it not that the horizon is obscured by low-lying banks of fog or darkness. The artificial horizon provides a means for eliminating

FIG. 31.



Side view of roll and pitch recorder.

these errors in observations of altitude, and makes it possible to accurately measure the altitude of any heavenly body that can be seen, whether or not the horizon is obscured. The first artificial horizon has just been completed and is now undergoing a test under the supervision of the authorities of the United States Naval Observatory.

Though they differ widely in the details of their construction and in the results to be accomplished, all applications of the gyroscope are founded on the phenomenon of inertia relative to space. This broadly useful principle gives us the means for maintaining a base line or fixed axis from which we operate to quench roll in the case of the stabilizing gyros; to hold the North and South meridian, as in the case of the gyro-compass; to control the ailerons and rudders of the aëroplanes; to record the movements of vessels in rolling and pitching, and to hold the mirror of the artificial horizon horizontal.

The knowledge obtained in the engineering applications of the gyroscope has opened a wonderful vista of possibilities for accomplishing results of the greatest usefulness to mankind.

Magnesite Deposits in Mexico. (*Board of Trade J.*, Jan. 9, 1913.)—The Consul at La Paz, Mexico, states that large deposits of high-grade magnesite, containing 92 per cent. of magnesium carbonate, are found near Magdalena. The largest bed is about 30 acres in area, and is situated on the Margarita Islands; deposits have also been found on Cedros Island. The mineral is so hard as to require blasting for removal. A company has been formed to develop these deposits. One calcining plant will be installed on Cedros Island and another on Margarita Island, each with a capacity of 200 tons per day.

New Leadless Storage Battery. ANON. (*Sci. Amer.*, cvii, 25, 527.)—A Swedish inventor has put on the market a new type of alkaline storage cell. The plates consist of inactive retainers which are loaded with active material, nickel oxyhydrate mixed with graphite in the positives, and a finely-divided alloy of iron and cadmium and certain other substances in the negatives. This new cell resembles the Edison cell, not only in the electro-chemical reaction, but also in the fact that extreme ingenuity is shown in the mechanical construction to obtain high efficiency in space and weight and durability.

THE CHEMISTRY OF THE SOIL NITROGEN.[1]

BY

SAMUEL L. JODIDI, B.S., Ph.D.

(CONTRIBUTION FROM THE CHEMICAL RESEARCH LABORATORY, SOILS SECTION, IOWA AGRICULTURAL EXPERIMENT STATION.)

THE question of plant food is one of the most important physiological problems confronting the plant physiologist, botanist, horticulturist, agronomist, forester, and, generally speaking, all those who have to deal with plants. It is of great moment both from a scientific and practical point of view. Increased knowledge as to how to utilize the plant food, especially the one which is already contained in the soil, seems to be the key for raising bigger crops and at less cost. It is with the soil nitrogen that this article is chiefly concerned with.

The nitrogen contained in soils is made up of ammonia, nitrites, nitrates, and of organic compounds. The latter usually form the bulk of the soil nitrogen. In speaking, however, of nitrogen as plant food we, in a more limited sense, usually mean by that the so-called available nitrogen which is necessary for the growth, development, multiplication, and, generally speaking, for all life functions of the plants.

It is true that available nitrogen—ammonia and nitrates—is constantly coming to the soil with all kinds of precipitations, like rain, dew, snow, etc. As is well known, however, the total amount of available nitrogen obtained in this way is only a few pounds per acre.[2] The nitrogen in the form of commercial fertilizers is quite expensive, costing about 18 cents per pound.

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[1] Communicated by the author.

[2] According to experiments conducted in Prussia, the total amount of nitrogen coming into the soil with atmospheric precipitations is from 11.6 to 18.2 kilogrammes per hectare (10.3 to 16.2 pounds per acre and year). See "Die Chemie in ihrer Anwendung auf Agricultur und Physiologie," J. v. Liebig, p. 44 (1876).

According to later experiments, the amount of atmospheric nitrogen which reaches the soil is still smaller.

True, the processes of Eyde and Haber will make it cheaper. Yet the cheapest and best source of nitrogen is the soil itself, which contains the remains of animals and plants, in all of which nitrogen is present, chiefly in the form of organic compounds. The latter, however, have not fully and advantageously been utilized because of our lack of knowledge concerning their chemical nature. In the light of the latest researches into the character of soil organic matter, and especially of soil organic nitrogen, the knowledge of the chemical nature of the organic nitrogenous compounds present in soils represents the very means for the solution of the problem as to how fully to utilize the soil nitrogen. In this connection it is well to bear in mind that available nitrogen, in a wider sense, consists not merely of ammonia and nitrates present as such in soils, but also of those organic nitrogenous compounds which readily undergo the processes of ammonification and nitrification.

As to the amount of ammonia present as such in Michigan peat soils, it was shown [3] to be quite small,—namely, from about one-tenth to one and one-half per cent. of the total nitrogen contained in the peat. This was also shown to be true of Iowa [4] soils in which the total quantity of ammoniacal and nitric nitrogen ranged from one to somewhat more than 2 per cent., calculated to the total soil nitrogen. The extension of our investigations has demonstrated that the above facts hold also good for Iowa soils which were fertilized with various organic materials and grew a considerable variety of crops.[5] In all of the above soils from 98 to 99 per cent. of the total soil nitrogen consisted of organic nitrogenous compounds. The extraction of these compounds by boiling the soils with sulphuric or hydrochloric acid led to results showing that those organic compounds [6] were made up chiefly of acid amides, diamino acids, and monoamino acids. Since, however, acids are known to hydrolyze proteins which are always present in soils, the question naturally arises: Are those acid amides and amino acids—found in the acid extracts of the soils—as such contained in the soils, or are they merely decomposition products of the hydrolyzed proteins?

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[3] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, 32, 396 (1910); also *Michigan Agr. College Exp. Sta. Techn. Bul.*, No. 4 (1909).

[4] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, 33, 1226 (1911); also *Iowa State College Agr. Exp. Sta. Research Bul.*, No. 1 (1911).

[5] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, 34, 94 (1912); also *Iowa State College Agr. Exp. Sta. Research Bul.*, No. 3 (1911).

[6] *Loc. cit.*

Just how much of the soil organic nitrogen is made up of proteins, and how much of acid amides, amino acids, or other nitrogenous compounds, and what the chemical nature of the latter is, cannot at present fully be answered. The investigations which systematically deal with the chemical nature of soil organic nitrogen date back only a few years and are still far from being completed. However, with the knowledge already at our command we are able to answer the above question in part.

The consideration of the fact that tissues of plants and animals, on their death, are constantly coming into the soil, is proof that the latter must contain a part of its nitrogen in the form of proteins. The work of S. Suzuki,[7] namely, "Studies on Humus Formation," led him to the conclusion that humic acid—obtained by extraction with a 2 per cent. sodium hydroxide solution—is made up of proteins which are combined more or less intimately with the black substances. As early as 1873 W. Wolf[8] made the assumption that the organic nitrogenous compounds present in soils are of the acid amide type. In their investigations in connection with amides Berthelot[9] and André found that hydrolyzing means, such as alkalies, acids, or even water, split off a portion of the nitrogen contained in humus in the form of ammonia. This, they concluded, must be due to the presence of amides in the soil. Based upon the fact that he found considerable amounts of ammonia in soils which were previously treated with acids or alkalies, but that ammonia as such was contained in the same soils in but minimum quantities, A. Baumann[10] suggested the possible presence of amino compounds in soils. The experiments of A. Hébert[11] have shown that when soil is heated with water to temperatures above 100° C. the organic nitrogenous substances present in the soil split off their nitrogen in the form of ammonia. The results of his experiments go to show that the ammonia thus obtained is due to the occurrence in the soil of amido compounds. While the presence of amino nitrogen in soils was qualitatively demonstrated by Warington[12] and Sestini,[13] Dojarenko[14] estimated quantitatively the amounts of amido and amino nitrogen present in humic acid which he extracted from Russian black soils. The isolation of a definite organic compound from an Hawaiian soil was accomplished by Shorey[15] in 1906, who identified it as picoline carboxylic acid.

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[7] *Bul. College Agr.*, Tokyo, 7, 513–529 (1907).

[8] *Landw. Jahrbücher*, 2, 389 (1873).

[9] *Compt. rend.*, 103, 1101 (1886).

[10] *Landw. Vers.-Stat.*, 33, 247 (1887).

[11] *Annales agronomiques*, 15, 355 (1889).

The writer[16] was the first to show the presence of diamino acids in soils. While their presence was first demonstrated by him through the application of the Hausmann[17] method as modified by Osborne[18] and Harris, it was later verified and confirmed by the writer,[19] as well as by other investigators,[20] in a variety of ways.

Inasmuch as the amino acids and acid amides make up a considerable part of the acid extract of soils, it may be worth while to consider here those compounds somewhat at length.

Theoretically, the primary disintegration products of proteins—acid amides, mono-amino acids, diamino acids—as well as lecithin derivatives, etc., may undergo chemical changes in the soil in a variety of ways. In case it is a simple hydrolytic process we would have the following equations:

$$\underset{\text{Acid amide.}}{R\cdot CO\cdot NH_2} + H_2O = \underset{\text{Fatty acid.}}{R\cdot CO\cdot OH} + NH_3$$

$$\underset{\text{Mono-amino acid.}}{R\cdot CH\cdot NH_2\cdot COOH} + H_2O = \underset{\text{Hydroxy acid.}}{R\cdot CH\cdot OH\cdot COOH} + NH_3$$

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[12] *Chem. News*, 55, 27 (1887).

[13] *Landw. Vers.-Stat.*, 51, 153 (1899). *Abs. in Expt. Sta. Rec.*, 10, 424 (1898).

[14] *Landw. Vers.-Stat.*, 56, 311 (1902).

[15] Annual Report of the Hawaii Agr. Exp. Sta., 1906, p. 52.

[16] *Journ. Amer. Chem. Soc.*, 32, 396 (1910); *Michigan Agr. Exp. Sta. Tech. Bul.*, No. 4.

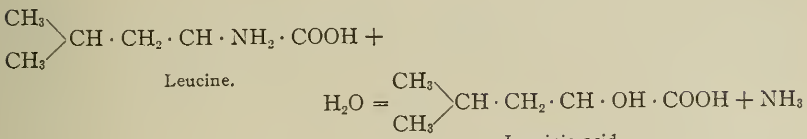
[17] *Zeit. physiol. Chem.*, 27, 95 (1899); 29, 136 (1900).

[18] *Journ. Amer. Chem. Soc.*, 25, 323 (1903).

[19] *Loc. cit.*

[20] *Journ. Biol. Chem.*, vol. viii, No. 5, p. 381 (1910).

In the latter case the leucine, for instance, would yield leucinic acid according to the equation:



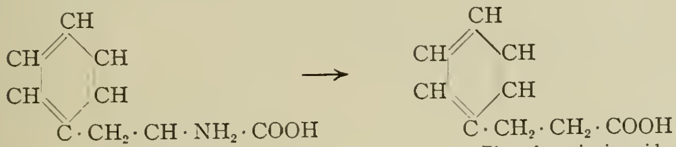
$$\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right> CH \cdot CH_2 \cdot CH \cdot NH_2 \cdot COOH + H_2O = \left.\begin{matrix}CH_3\\CH_3\end{matrix}\right> CH \cdot CH_2 \cdot CH \cdot OH \cdot COOH + NH_3$$

Leucine. Leucinic acid.

Deamination of mono-amino acids can take place in such a way as to produce fatty acids according to the following schemes:

$$CH_3 \cdot CH \cdot NH_2 \cdot COOH \longrightarrow CH_3 \cdot CH_2 \cdot COOH$$

Alanine. Propionic acid.

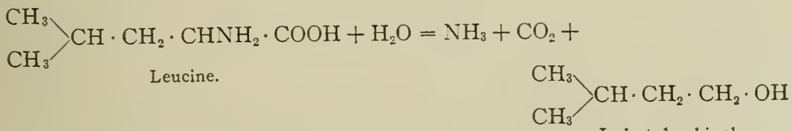


Phenylalanine. Phenylpropionic acid.

$$COOH \cdot CH_2 \cdot CH \cdot NH_2 \cdot COOH \longrightarrow COOH \cdot CH_2 \cdot CH_2 \cdot COOH$$

Aspartic acid. Succinic acid.

Through fermentation the amino acids can yield alcohols. Leucine, *e.g.*, can give isobutylcarbinol (amylalcohol) according to the following equation:



$$\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right> CH \cdot CH_2 \cdot CHNH_2 \cdot COOH + H_2O = NH_3 + CO_2 + \left.\begin{matrix}CH_3\\CH_3\end{matrix}\right> CH \cdot CH_2 \cdot CH_2 \cdot OH$$

Leucine. Isobutylcarbinol.

Again, the diamino acids may split off CO_2 under the formation of amines. Lysine,[21] for instance, is known to split off

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[21] *Zeit. physiol. Chem.*, 29, 334 (1900).

CO_2, under the action of micro-organisms, whereby cadaverine (pentamethylene diamine) results:

$$NH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH\cdot NH_2\cdot COOH \longrightarrow CO_2 +$$

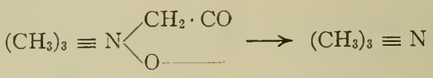
Lysine.

$$NH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot NH_2\cdot$$

Cadaverine.

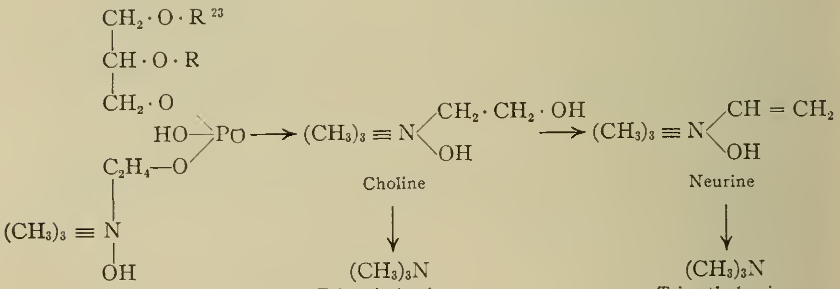
In this connection it is interesting to note that the amines choline[22] and trimethylamine were extracted from the soil. There can be little doubt, if any, that trimethylamine was formed in the soil secondarily from betaine, choline, and neurine, of which betaine is as such widely distributed in the vegetable kingdom, and the neurine is closely related to choline, which latter, in turn, is a decomposition product of lecithin.

The above can best be illustrated in the following way:



$$(CH_3)_3 \equiv N\begin{cases} CH_2\cdot CO \\ O\text{———} \end{cases} \longrightarrow (CH_3)_3 \equiv N$$

Betaine. Trimethylamine.



$CH_2\cdot O\cdot R$ [23]
$CH\cdot O\cdot R$
$CH_2\cdot O$
$HO—PO$
$C_2H_4—O$
$(CH_3)_3 \equiv N$
OH
$(CH_3)_3 \equiv N$ $CH_2\cdot CH_2\cdot OH$ OH
Choline
$(CH_3)_3 \equiv N$ $CH = CH_2$ OH
Neurine
$(CH_3)_3N$
$(CH_3)_3N$

Lecithin. Trimethylamine. Trimethylamine.

The trimethylamine having been found in the soil, it is but reasonable to assume that methylamine and dimethylamine will also be found in soils, since the above three amines equally occur as degradation products of rotted flesh, of lecithin-holding substances, etc.

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[22] Shorey, E. C., original communications, VIII Intern. Congress of Appl. Chem., vol. xv, p. 249.

[23] R stands for the radical of the fatty acids, like palmitic, stearic, oleic, etc.

Just as cadaverine can result secondarily from lysine—a primary cleavage product of proteins—putrescine can result secondarily from ornithine, which can be formed, *e.g.*, from the protein cleavage product arginine through the enzyme arginase, or from ornithuric acid through hydrolysis. Hence, the occurrence in the soil of cadaverine, putrescine, and related amines is altogether not out of the question.

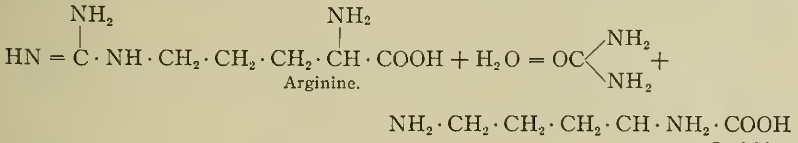
The above can best be illustrated by the following equations:

$$NH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH \cdot NH_2 \cdot COOH = CO_2 + NH_2 \cdot (CH_2)_5 \cdot NH_2$$

Lysine. Cadaverine.

$$NH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH \cdot NH_2 \cdot COOH = CO_2 + NH_2 \cdot (CH_2)_4 \cdot NH_2 \cdot$$

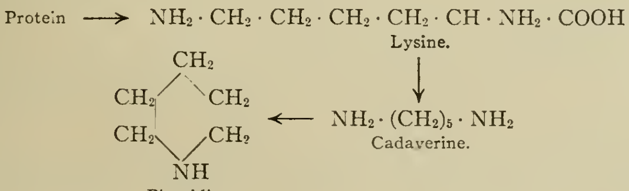
Ornithine. Putrescine.



$$HN = \overset{\overset{NH_2}{|}}{C} \cdot NH \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot \overset{\overset{NH_2}{|}}{CH} \cdot COOH + H_2O = OC\begin{matrix} NH_2 \\ NH_2 \end{matrix} + NH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH \cdot NH_2 \cdot COOH$$

Arginine. Ornithine.

The occurrence in the soil of picoline carboxylic acid, as well as of other pyridine derivatives, may very well be due to the existence in the soil of vegetable residues containing a pyridine nucleus, bearing in mind that many plants produce alkaloids all of which are closely related to pyridine, their parent body. However, pyridine and its derivatives may also be formed from proteins. Lysine, for instance, which is a primary cleavage product of proteins, is known, under the action of micro-organisms, to yield pentamethylene diamine. The hydrochloride of the latter yields, on distillation, piperidine, which is hexahydropyridine. The above facts may find expression in the following way:



There can hardly be any doubt but that the primary formation of lysine from proteins and the secondary degradation of lysine to cadaverine actually take place in the soil, since lysine[24] could be extracted from soils, and this diamino acid is known under the action of bacteria—so numerous in the soil—to split off carbon dioxide under the formation of pentamethylene diamine. Whether the latter can, under the influence of the agencies active in the soil, be converted into piperidine has not yet been demonstrated.

Proteins, however, can, in the process of decomposition, yield pyridine compounds also in another way. It is fairly well known that some of the primary decomposition products of proteins, like lysine, tyrosine, tryptophane, and glucoseamine, secondarily yield humin substances. The latter, in turn, as was shown by Samuely,[25] yield, on reduction, pyridine.

Intermediary products can be, and actually are being, formed in the soil when conditions in it are favorable for the process of putrefaction. When, however, conditions in the soil are favorable for the process of cremacansis—in case the soil is well drained, porous, well cultivated, and hence contains a good deal of air—the organic substances will naturally, sooner or later, completely be destroyed under the formation of carbon dioxide, water, and ammonia.

Do amino acids, acid amides, purine bases, etc., as such, occur in the soil? This question must be answered in the affirmative. Aside from the fact that some of these compounds may come into the soil with manures, or may be formed in it as the result of degradation of protein bodies, we must not forget that the nitrogen in plants consists in part of amino acids as such. E. Schulze,[26] for instance, has shown that in beets but 21.6–38.9 per cent. and in potatoes only 56.2 per cent. of the total nitrogen consists of protein bodies. Further, it was found by O. Kellner[27] that amino acids and acid amides occur quite generally in plants, sometimes in very considerable proportions. It matters little whether those compounds are the result of degradation of proteins through the action of proteolytic enzymes, which is especially the case in germs of plants or in the young sprouts, or whether they represent transition products from the inorganic nitrogen (taken up by the plants) to the synthesis of proteins in the vegetable organism. The fact remains that acid amides and amino acids as such occur in plants, and hence they naturally come, on the death of the plants, into the soil.

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[24] Original communications, VIII Inter. Congress of Applied Chemistry, vol. xv, p. 249.

[25] *Beitr. Chem. Physiol. u. Path.*, 2, 355 (1902).

[26] *Landw. Versuchsst.*, 18, 320 (1875); 21, 86 (1878); 69, 393 (1908).

[27] *Landw. Yahrb.*, 8 (1879).

The above statement does not stand in contradiction to the fact that water extracts of soils usually contain but small amounts of nitrogenous bodies other than ammonia and nitrates. It should be borne in mind that many organic nitrogenous compounds, especially the amino acids, are able to combine with mineral bases acids or salts in order to form double compounds. The latter show physical properties different from the amino acids, acid amides, etc., so far as, *e.g.*, solubility in water is concerned.

Again, amino acids,[28] purine bases,[29] pyrimidine derivatives [30] and other [31] non-protein substances have directly been isolated at room temperature from a considerable number of soils,—namely, from weak (2 per cent.) sodium hydroxide soil extracts. Under these conditions of the isolation of the above compounds hydrolysis of protein substances cannot very well be assumed.

The chemistry, then, of the organic nitrogenous compounds in soils can at present broadly be stated as follows: Under the action of proteolytic enzymes, micro-organisms, or chemical means, the proteins are decomposed—probably through the stages of albumoses, peptones, and polypeptides—chiefly to diamino acids, mono-amino acids, and acid amides. In addition to these products, there results also nucleic acid, in the case of nucleoproteids, which latter, on decomposition, yield nucleins, and, further, proteins on the one hand, and purine bases, pyrimidine derivatives on the other. Furthermore, some non-protein substances like acid amides and amino acids, as stated already, come as such into the soil with certain plants.

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[28] *Journ. Biol. Chem.*, vol. viii, No. 5, p. 381 (1910).

[29] *Journ. Biol. Chem.*, vol. viii, No. 5, p. 385 (1910).

[30] *Ibid.*

[31] Ann. Report Hawaii Agr. Exp. Sta., p. 37 (1906); *Journ. Amer. Chem. Soc.*, 34, 99 (1912).

As to the accumulation in the soil of the nitrogenous compounds, it can safely be stated that the compounds which are more resistant to the above-mentioned agencies will be found in the soil in larger proportions than the less resistant substances. The amino acids and acid amides cannot accumulate in the soil to any extent, because they are easily ammonified in it, as was shown in a recent publication.[32]

It does not make, however, much difference whether at any time the acid amides and amino acids are present in the soil in smaller or larger quantities, if only the higher complex molecules of the proteins and nucleoproteids have to pass through the stage of the acid amides and amino acids before their nitrogen can be transformed into ammonia.

The ammonia and nitrites, too, cannot accumulate in the soil, because of their ready oxidation to nitrates, which latter, again, are ordinarily encountered in soils in but small quantities, for the reason that they are eagerly taken up by plants, or leached out of the soil in case it is followed.

It is only soil nitrogen in its initial stage—proteins and nucleoproteids—that is commonly present in considerable quantities in the soil. The nitrogen in its final stage—nitrates—can, under certain conditions, accumulate in the soil. All other forms of nitrogen, both organic and inorganic compounds, represent transition stages and seem to be present in soils in but inconsiderable proportions. The acid amides and amino acids represent some of the organic nitrogenous compounds out of which ammonia is immediately formed.

It thus can be seen that many of the organic nitrogenous compounds represent a great and important source from which the available nitrogen—ammonia and nitrates—is formed. Consequently, the problem of the formation and utilization of the available soil nitrogen is one which is intimately connected with the question of the chemical nature of the organic nitrogen.

Schematically the chemistry of the soil nitrogen may be presented as follows:

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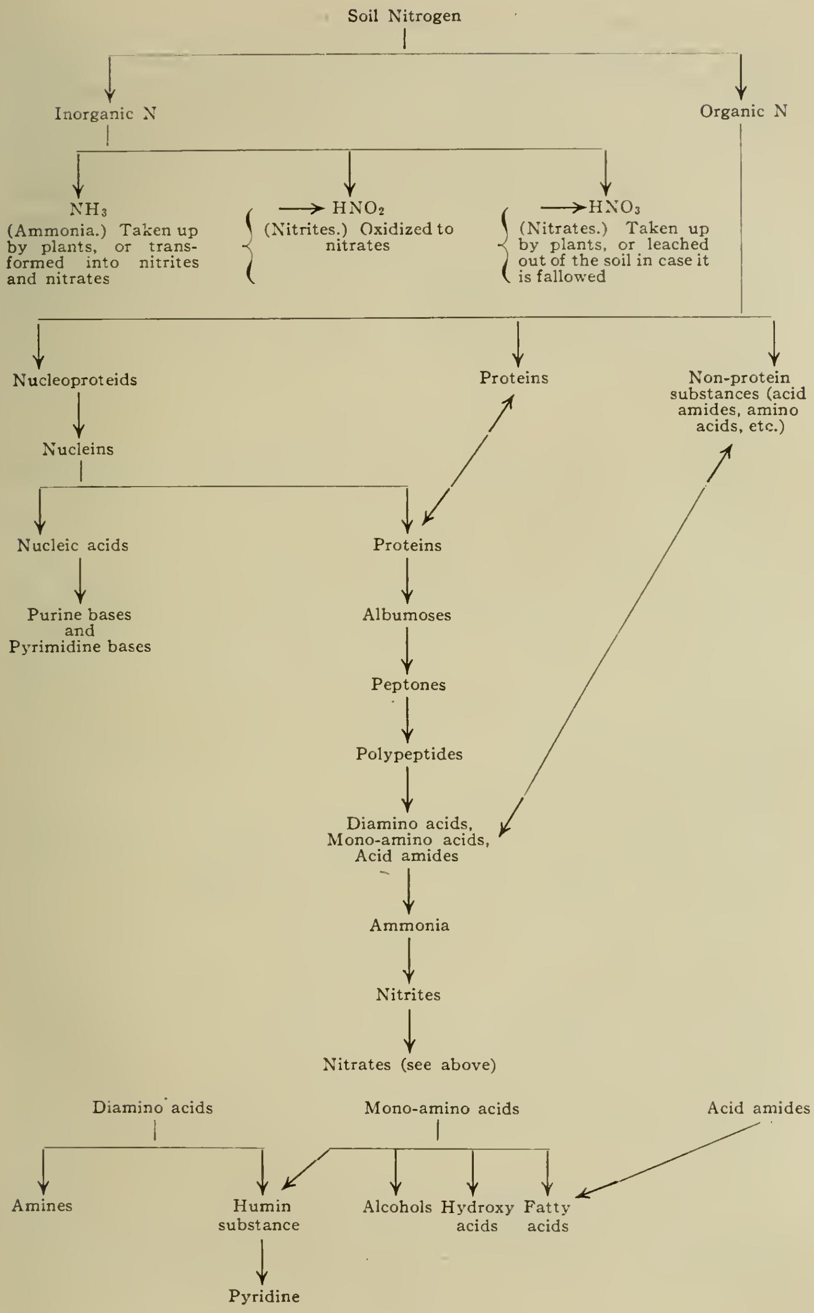
[32] Jodidi, S. L., original communications, VIII International Congress of Applied Chemistry, vol. 26, p. 119.


Soil Nitrogen
Inorganic N
Organic N
NH_3
(Ammonia.) Taken up by plants, or transformed into nitrites and nitrates
HNO_2
(Nitrites.) Oxidized to nitrates
HNO_3
(Nitrates.) Taken up by plants, or leached out of the soil in case it is fallowed
Nucleoproteids
Proteins
Non-protein substances (acid amides, amino acids, etc.)
Nucleins
Nucleic acids
Proteins
Purine bases and Pyrimidine bases
Albumoses
Peptones
Polypeptides
Diamino acids, Mono-amino acids, Acid amides
Ammonia
Nitrites
Nitrates (see above)
Diamino acids
Mono-amino acids
Acid amides
Amines
Humin substance
Alcohols
Hydroxy acids
Fatty acids
Pyridine

In considering the above scheme it should be borne in mind that it contains compounds which have actually been found in soils, or which, from theoretical considerations, are likely to occur in soils. This scheme, however, does not represent the only way in which the various compounds may be formed in the soil. For instance, alcohols, fatty and hydroxy acids, can occur in the soil as the result of fermentation of carbohydrates. Equally, organic acids may be formed through oxidation of alcohols or through hydrolysis of naturally-occurring fats. However, a closer consideration of these and similar processes is beyond the province of this article.

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The Specific Heat of Fibrous Materials. OTTO DIETZ. (*Wochbl. Papierfabr.*, xliii, 3119.)—The specific heats of the animal and vegetable fibres vary only slightly from one another, and are between the limits 0.319 and 0.331, so far as cotton, silk, wool, linen, hemp, wood-pulp, artificial silk, etc., are concerned. The mineral fibres have lower specific heats: thus, that of asbestos is 0.251 and that of glass-wool is 0.157. The specific heat is practically unaffected by temperature or content of moisture.

Helium in Gases from Springs. C. MOUREU and A. LEPAPE. (*Comptes Rendus*, clv, 197.)—While the rare gases argon, krypton, xenon, and neon seem to occur in natural springs approximately in quantities of the same order as in the atmosphere, the percentage of helium is sometimes far higher, and some springs in the Côte d'Or contain 10 per cent. of helium in their total gas content, consisting of nitrogen and the rare gases. The Source Carnot at Santenaz yields 17,845 litres of helium per annum. This helium might be "young" (*i.e.*, liberated as it is formed) or "fossil" (*i.e.*, liberated after long accumulation). The first assumption would require the disintegration of 91 tons of radium or of 500 million tons of pitchblende per year for the production of the helium, hence this seems out of the question.

Foreign Lighting Practice. DR. L. BELL. (*Elec. World,* lx, 17, 875.)—In the early days of the metallic filament lamp and of the flame arc the United States was behind Europe, but at present has quite caught up. When the long-burning flame arc appeared in Europe three or four years ago the work of development was taken up here, and this country soon reached an equality. Metallic filament lamps have been largely developed abroad, especially for small units and lamps of high voltage. The 15-watt tungsten lamp for 110 volts was quickly followed by a similar development here. The latest foreign development is a wire-drawn tungsten lamp for voltages from 90 to 120, consuming only 7 watts and giving 5 candle-power. Abroad, as here, arc lamps with the long-burning flames are making progress, but the short-burning flame still holds an important place. One type of short-burning flame, not known to any considerable extent here, seems to have a considerable usage,—*i.e.,* the flame lamp at low wattage, say 300 or less, and working at a voltage that permits a pair of lamps to be worked in series on the ordinary low-tension circuit. Then should be mentioned the cadmium amalgam quartz arc, which works very similarly to the ordinary quartz arc, but metallic cadmium held vaporized by the arc is the chief source of light, just enough mercury being added to bring the color from the reddish of cadmium to a pretty good white. The most interesting lamp of foreign origin is the neon tube, on the principle of the Moore light, but using neon as the illuminescent gas. The color is a beautiful deep orange, and gives an efficiency considerably better than any other gas hitherto tried—as low, it is claimed, as 0.8 watt per mean spherical candle-power for a tube about twenty feet long.

The Origin of β and γ Rays from Radioactive Substances. E. RUTHERFORD. (*Eng.,* xciv, No. 2442, 549.)—In all cases one α particle is expelled per atom, with the single exception of thorium C, which gave two α particles of different velocities per atom. The β rays were very complex, according to Hahn and Meitner and others. In a magnetic field a single β ray would be spread out into a fan with curved lines, and when the photographic plate was placed sideways each of these lines appeared as a circle. A substance might give upwards of 15, even 30, radiations; and if they were all simply β rays the facts were difficult to explain. He agreed with Bragg, that the β rays, in escaping and passing through different regions, had different amounts of energy abstracted from them, and he gave simple algebraic formulæ connecting these rays from RaB and RaC. Some β rays were converted into γ rays; the β rays were changed by passing through matter, whilst the γ rays were the characteristic rays of the radium atom. Professor Bragg agreed that the energy diminished by leaps. Professor Soddy thought the γ rays seemed to come from the slow rather than from the fast β rays.

NOTE ON THE CONSTRUCTION OF THERMOPILES FOR MONOCHROMATIC ILLUMINATORS.*

BY

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One of the most difficult problems that confronts experimenters who use light stimuli is the measurement of the energy value of these stimuli.

High intensity and high spectral purity are incompatible. The common mistake made by instrument makers is the construction of a spectroscope (illuminator) with a high dispersion and a low light-gathering power. The lenses may be *f/6* when they ought to have an aperture of *f/3*. The result is what one would expect (judging from the standpoint of the victim who attempts to measure the energy in the spectrum of any of our common light sources), viz.: the attempt to measure the energy is practically a failure, especially in the violet and in the ultra-violet. This explains why, in marked contrast with the infra-red, the visible spectrum has gone all these years unmeasured. Much pioneering work is needed in the visible and in the ultra-violet, and, until we have some idea as to whether it is worth while to use high dispersion, it seems desirable to sacrifice spectral purity in order to get a start in the radiation measurements.

THE SPECTROSCOPE.

The spectroscope constructed for the purpose is a simple device, the main feature being that it is entirely enclosed to exclude extraneous light. Two pairs of telescope lenses are provided: (1) a pair of triple-achromatic lenses made by Zeiss, 6 cm. in diameter and 18 cm. focal length, and (2) a pair of plano-convex lenses of quartz, 6 cm. in diameter and 18 cm. focal length. Combined with a 60° quartz prism the latter is used in the ultra-violet. There is much less loss of light in the simple (quartz) lenses, and the change in focal length is of minor importance, especially when measuring spectral lines. This is owing to the fact that the focal length of the collimating lens is kept fixed, so that the same amount of energy, of all wave-lengths, emerges from the collimating lens and passes through the prism to the objective lens. In passing from the extreme red to the extreme ultra-violet the aperture increases from *f/3* to about *f/2.5* as the result of refocusing, but the objective transmits to the thermopile slit the same proportion of light, of all wave-lengths. Theoretically of course, the focal length of the collimator should also be varied so that all wave-lengths will leave the collimator in parallel rays, but this is of minor importance.

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* Communicated by the author.

THE THERMOPILE.

In order to measure correctly the energy in the spectrum, when the focal length has to be varied, it is necessary to use a receiver that is completely opaque to the incident radiations. It was to satisfy this requirement that the bismuth-silver thermopile,[1] with a completely opaque receiver, was designed. Silver wire was used because it contributes but very little in resistance and it is easy to manipulate. As mentioned in the above-cited papers, iron has a high resistance, it rusts off easily, and for these reasons the writer does not recommend its use.

The slight additional electromotive force gained in a bismuth-iron thermopile may be obtained in a bismuth-silver thermopile by adding several more thermo-junctions in the same length occupied by the bismuth-iron junctions. This is advantageous, for the sensitivity is proportional to the square root of the exposed surface, and it is desirable to place as many junctions as possible within a given area (length of exposed surface, for the width is quite predetermined by the dispersion, and hence the width of the slit). For example, suppose we use individual receivers 1 mm. wide and desire to build a receiver 4 mm. long. If we use four individual receivers 1 mm. long the galvanometer deflection will be four times that caused by a single receiver 1 mm. long. If we use but a single receiver 4 mm. long, then the deflection is only twice $(\sqrt{4})$ that of a receiver 1 mm. long. Of course, the latter is the simpler to construct, and that is where the commercial instrument builder makes a mistake. It is not sufficient to use bismuth-iron, which has a slightly higher thermal electromotive force, in order to manage with a less number of thermojunctions, as will be shown presently.

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[1] Journal Franklin Institute, December, 1911, and February, 1913; *Bulletin Bureau of Standards*, 9, p. 7, 1912.

The following tests were made to determine the relative sensitivity of bismuth-iron (steel) and bismuth-silver thermopiles:

To one end of a bismuth wire, 0.1 mm. in diameter and 5 mm. in length, was soldered an *iron* wire 0.0308 mm. in diameter, and to the other end was soldered a *silver* wire 0.0308 mm. in diameter. In both cases the diameters of the wires are very close to the theoretical values required for maximum sensitivity. The ends of the silver and of the iron wire were tinned (as described in the previous paper), in order to obtain a thorough junction with the bismuth. To each junction was welded a tin receiver 2 by 1 by 0.025 mm. (as actually used in practice), which was painted with lamp-black and then blackened still more with soot from a sperm candle. Such a pair of junctions was then enclosed in an air-tight receptacle to eliminate air currents. A standard incandescent lamp, with a shutter in front of it, was placed at a distance of about 1.5 m. from this thermo-element, and the receivers were exposed alternately (also simultaneously for the differential effect) to the standard source of radiation. The result of several such tests showed that the radiation sensitivity of the bismuth-iron (steel) junction was about 22 to 23 per cent. higher than that of the bismuth-silver junction. In other words, using the same sized receivers it would require only about four-fifths as many bismuth-iron junctions as it would require bismuth-silver junctions in constructing a thermopile. But, as it will be shown presently, the resistance of the bismuth-iron thermopile will be almost three times as great as that of a bismuth-silver thermopile, which is of the order of 8 to 9 ohms. Now, the physical laboratories are usually equipped with low-resistance galvanometers, and it will be necessary to construct new ones having a resistance comparable with the bismuth-iron thermopile, or it will be desirable to use a bismuth-silver thermopile.

A test was made of the radiation sensitivity of iron wires 0.0308 mm. and 0.0418 mm. in diameter (joined to bismuth wire 0.1 mm. in diameter; with receivers as in the Bi-Fe and Bi-Ag test) to determine whether the thicker wire, which has only one-half the resistance of the 0.03 mm. wire, can be used. The test showed that the 0.03 mm. wire (iron), against bismuth 0.1 mm. in diameter, had a radiation sensitivity 9 to 10 per cent. higher than the 0.04-mm. iron wire, so that what is gained in eliminating the resistance is lost in radiation sensitivity.

The "iron" wire usually obtainable on the market is steel having a thermo-electric power of about 11 microvolts at 20°. The particular sample (0.03 mm.) tested against bismuth (0.1 mm.) had a thermo-electric power of 83 microvolts, while a bismuth-silver thermocouple had a thermo-electric power of 75 microvolts. Another sample of bismuth (0.1 mm. in diameter) against this same sample of silver had a thermo-electric power of 81 microvolts. A sample of bismuth 0.15 mm. (against silver) gave 86 microvolts, which is close to the value (89 microvolts, mentioned in the previous paper) obtained on another sample of 0.15 mm. wire. Apparently the thick wires give a higher electromotive force, which is probably to be expected from the experiments of Matthiesen. These tests show the necessity of examining the different samples of bismuth wire in order to be able to select the one giving the highest electromotive force.

The samples of iron (steel) wire 0.0308 mm. in diameter were found to have a resistance of 0.21 to 0.23 ohm per millimetre. The bismuth wire 0.1 mm. in diameter had a resistance of 0.10 to 0.11 ohm per millimetre. It requires about 4 mm. of bismuth (averages 0.41 to 0.43 ohm) per thermo-junction. The resistance of the silver wire is negligible. Two thermopiles of twenty elements each of bismuth-silver had a resistance of 8.3 and 8.6 ohms respectively. A different sample of bismuth wire would, of course, give a slightly different result (*e.g.,* another sample tested 0.12 ohm per mm. Its thermo-electric power against silver was 77 microvolts). Turning now to the question of the substitution of iron for silver, it is to be noticed that the shortest possible length that can be used is about 2 mm., or 4 to 5 mm. for the two pieces joined to the ends of the bismuth wire. This makes a resistance of 0.8 to 1.0 ohm; to which must be added 0.4 ohm for the bismuth, so that the resistance is 1.2 to 1.5 ohms per thermo-element. Since from four-fifths to three-fourths as many elements will be required as in the bismuth-silver thermopile of 20 junctions, in order to attain the same radiation sensitivity, the resistance of a bismuth-iron thermopile of 15 (or 16) junctions will be from 22 to 24 ohms.

Owing to the greater difficulty in annealing and tinning the iron wire, which requires an acid cleaner in order to insure good contact in making the soldered joint; also owing to rusting, and to the undesirability of using corrosive substances (the material commonly used in soldering is zinc chloride) in soldering the junctions, the bismuth-silver thermopile is found to be the easier to construct and it promises to be the more long-lived. Its novelty is the completely opaque receiving surface, which makes it as useful as a bolometer (which it equals in sensitivity) with none of the disadvantages of the latter. By exhausting the air to 0.1 mm. with an oil pump the sensitivity is doubled. By attaching the receivers to the junctions with shellac instead of solder the radiation sensitivity is reduced about 9 per cent.

The foregoing tests were made to satisfy myself as to a claim made that the bismuth-iron thermopile is a far more sensitive instrument. The results show that, as found in the previous paper, by adding several more junctions of bismuth-silver in the space occupied by a bismuth-iron thermopile it will not be inferior to the latter in its radiation sensitivity. The writer therefore feels no necessity for changing the conclusions arrived at in the preceding paper, as to the relative merits of those two thermopiles. The choice seems to be a personal one, with low resistance, ease of construction, and lasting qualities in favor of the bismuth-silver combination. At present an attempt is being made to have annealed wire drawn from the Hutchin alloys, Bi + 5 per cent. Sn and Bi + 3 per cent. Sb, which have a much higher thermo-electric power than pure bismuth. Whether the increased resistance justifies their use remains to be determined.

WASHINGTON, D. C., March 14, 1913.[2]

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[2] Since writing this, R. Fuess, Steglitz-Berlin, has informed me that he will use this thermopile with his new high intensity monochromator. This thermopile, mounted upon an appropriate stand, may also be obtained from the Cambridge Scientific Instrument Company, Cambridge, England.

Tantalum Electrodes. O. BRUNCK. (*Chem. Zeit.*, xxxvi, 1233.)—Metallic tantalum, which was originally manufactured solely for use in metal filament electric lamps, has recently been introduced as a substitute for platinum for certain purposes. Shaped articles of tantalum are sold at M. 2.50 per gramme, about $17 per ounce. Below 200° C. tantalum is not attacked by air nor oxygen nor acids, with the exception of concentrated hydrofluoric acid; it is not attacked by *aqua regia*. Aqueous solutions of alkalies do not attack it, but fused alkalies do. When heated, it oxidizes at a temperature considerably below red heat. It is very useful for surgical and dental instruments, and has been found very suitable as a substitute for platinum for electrodes, especially for electro-analysis. As cathode, tantalum can replace platinum in all cases, but when used as anode it becomes coated with a badly-conducting film of dark-blue tantalum oxide, and for this purpose it is necessary to coat it electrolytically with a thin deposit of platinum before use. When used as cathode for the electrolytic determination of metals, tantalum possesses this advantage, that the deposits can be removed from the electrode by dissolving in acid or *aqua regia*. Zinc and cadmium show no tendency to alloy with tantalum when deposited thereon. Another advantage of tantalum as compared with platinum, apart from the difference in price of the two metals, is that tantalum has a specific gravity of only 16.6, compared with 21.48 for platinum, hence less metal is needed to make articles of a given size. Tantalum electrodes could also be used in place of platinum in the electrolysis of alkali chloride solutions for the manufacture of hypochlorites or bleaching solutions.

Pinch Effect Furnace. CARL HERING. (*Met. Chem. Eng.*, x, 196.)—After repeated runs on bronze, steel, and steel alloys, the holes containing the resistor part of the bath show no increase in size; on the other hand, in some cases a decrease was noted, due to a hard, smooth, black coating, presumably of oxides and other impurities combining with the magnesite. If any change should occur it can be compensated by regulating the transformers to give a higher amperage at a lower voltage. The freezing of the charge does no harm, for the furnaces have been repeatedly started in the morning on the remains of the frozen charge of the previous day.

Asbestos in the United States. J. S. DILLER. (*J. Can. Min. Inst.*, xiv, 93.)—This is a geological paper and deals with the nature of the asbestos deposits of the United States. Only two of the four different types of deposits are worked commercially, viz.: (1) cross-fibre veins of chrysotile asbestos in serpentine in Vermont; and (2) mass-fibre amphibole asbestos in Georgia and Idaho. The production of asbestos in the United States is over 3000 tons, or about 5 per cent. of the production in Canada, which constitutes by far the largest part of the world's total output.

THE MEASUREMENT OF THE TRUE STATIC PRESSURE IN A MOVING FLUID—APPLICATION TO AN AËROPLANE BAROGRAPH.

BY

DR. A. F. ZAHM.

As yet no very convenient instrument or method, of general applicability, for finding the precise altitude of an aëroplane in flight appears to be available. In some favored localities, as at Lake Keuka or Fort Myer, it is practicable to have accurate bench marks on the side of a steep hill, or on a lofty tower, from which to sight over the aviation course, and thus to observe precisely whether the machine has risen above a prescribed elevation. This method serves in altitude tests for pilot licenses when but a single predesignated height has to be measured; but, besides being restricted to favored localities, it cannot be practically used to give a continuous story of the altitude from instant to instant. An elaborate system of triangulation can be employed, with some accuracy, for flights over a limited field in any locality; but it is very tedious in all cases, and is inapplicable to cross-country voyages. Various other methods may be suggested, but, aside from the barometric one, none of these have come into general practice.

In the use of the recording barometer, or barograph, curious errors arise, which may perplex or baffle the observer charged with the responsibility of taking the altitude; and, indeed, may not a little vex him when some great trophy, cash prize, or world's record is at stake. In principle the barograph is supposed to reveal the altitude of flight by recording continuously and accurately the pressure, from which the observer computes the elevation according to an assumed law connecting the altitude and atmospheric pressure. We need not tarry over the sensibilities of this law to every transient fluctuation of moisture, of temperature, and of aërial turbulence, but allow that their effects have been circumvented or minimized.

The task now is to obtain true pressure records. We will suppose that the instrument is so suspended on the flier that the recording pen will not, by shaking or otherwise, blur the record.

We will suppose that the lag of the pen due to friction or fatigue of the straining metal of the barograph cistern has been obviated or perfectly met by previous calibration; in a word, that the barograph record discloses the true pressure *within* the box, or case holding the instrument. Under these very favorable circumstances we may inquire what is the pressure in the air just outside the box.

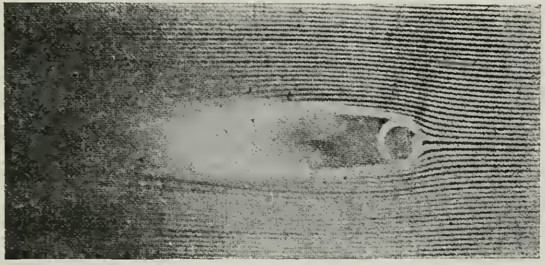
The passive balloonist is not troubled by this query. He knows that, as he drifts with the tide of the air, the static pressure is identical inside and outside the instrument case. But on an aëroplane or motor balloon the air-stream rushes swiftly by the instrument case, and in general causes either suction or increase of pressure inside the case, where the barograph is mounted. One may put the case itself inside another box to avoid the air rush, but without avail; the larger box meets the air rush, suffers a consequent change of internal pressure, and so advantages nothing. The question then is to correct for this change of pressure, or, better still, to obviate it by use of an instrument case whose internal pressure is unaffected by the air rush. To design such a case is substantially the question before us. Let us first have a working principle on which to base the design.

When any fluid is in steady motion relative to an immersed solid, it appears to flow past the body in definite stream-lines. If the flow be uniform, the stream-lines, or paths of the individual particles, are parallel everywhere in the fluid except in the region where it courses round the body. In the region of the body the stream-lines, if rendered visible, are, in general, seen to crowd more closely together in some places, and to diverge more or less in other places, as illustrated in the accompanying figure (Fig. 1). Now, by a well-known theorem in fluid dynamics first proved by Bernouilli, the diverging of the stream-lines, at any point in a level stream of liquid, signifies an increase of pressure there, while a crowding signifies diminution of pressure. If, therefore, any fair figure immersed in such a liquid stream have a portion of its surface invested by stream-lines unchanged in relative spacing from that they enjoyed in the undeviated current, that portion of the surface must sustain the same pressure as prevails in the unchecked stream at the same level. The free air is, of course, not sufficiently incompressible to comply strictly with Bernouilli's theorem; but for ordinary speeds of transportation it does so with ample approximation for the purpose in hand. This has been proved mathematically and experimentally elsewhere by the present writer.[1]

Having, then, such a fair figure in a uniform level stream, say of air, if its surface be perforated at any point of unchanged stream-line spacing, the pressure within must, provided there occur no material leakage, be the same as in the undeviated current. Hence if such figure form the barograph case, or be hermetically connected therewith, the instrument will sustain and, other things perfect, truly record the static pressure of the general and undisturbed air-stream.

Starting with this basic principle, an indefinite number of figures having "neutral" spots, or places of unchanged pressure, on their surface, may be rationally designed or discovered by systematic experimentation in a uniform current. If the inventor can recall from his visual experience, or rationally devise, a surface which at some spot shall have unstrained flow,—*i.e.*, unstrained spacing of the stream-lines,—he can use that spot, duly perforated, for a collector of the true static pressure desired. A thin plane moving edgewise through the fluid, a thin open tube moving endwise, a nicely pointed narrow cylinder or closed pipe moving dart-like, obviously has some such neutral points well back of the entering edge or point. A sphere, a torpedo form moving axially, has a ring of neutral points which, as shown by Finzi and Soldati (Fig. 2), can be located experimentally. And so for many other figures submerged in a uniform stream.

FIG. 1.



Stream-lines about a fixed cylinder transverse to a uniform stream of air.

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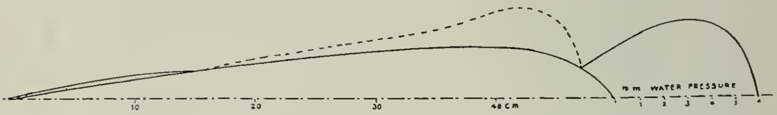
[1] *Physical Review,* Dec., 1903.

In practice the air rush past a barograph, especially on a slow flier in a turbulent atmosphere, may be far from uniform; for the apparent fluctuation of speed and direction, referred to a body advancing through a fluid, is inversely as its speed. If the fluctuations be considerable, the above-mentioned shapes may not have fixed neutral spots on their surface, and consequently may not transmit the true static pressure. For example, the thin plane above mentioned experiences the true static pressure of the medium, while advancing exactly edgewise; but, when striking the air at a slight angle, sustains marked suction on the lee side, and compression on the other. So also for the pointed rod or tube. Of course, these shapes can be pivoted so as always to meet the wind directly. But this precaution may be rendered unnecessary by use of guiding blades; for, as the writer has found in wind-tunnel experiments, when the air blows through a honeycomb of guiding blades, say of thinnest steel, there is very slight disturbance of the stream-line spacing, even when the wind varies considerably in direction. And so in general for parallel thin surfaces placed edgewise to the general direction of the current. An open tube with thin walls is a good example; its inner surface well back from the mouth should sustain nearly the true static pressure, and therefore may well be perforated and connected by suitable tubing to the instrument case of the barometer.

FIG. 2.

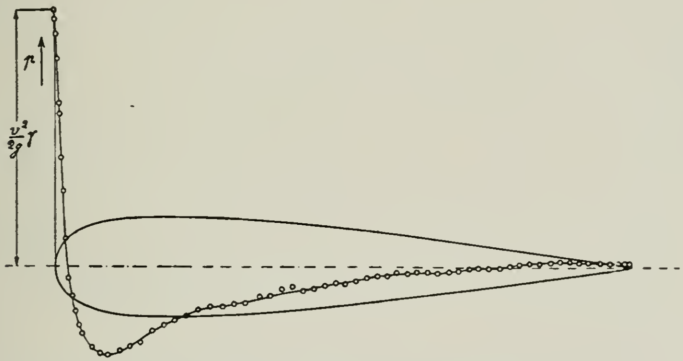


Distribution of air pressure on torpedo-shaped model, moving large end first, ten metres per second. Surface pressure in millimetres of water, at ten metres per second, measured perpendicular to surface. Heavy lines indicate excess over normal atmospheric pressure; dotted line indicates defect of pressure.

There is a "wire sandwich" collector alleged to be competent to gather and transmit the true static pressure, whatever the directional fluctuation of the wind. It consists of two thin circular discs pressing between them a wire screen which projects slightly beyond their edges. This sandwich is alleged to experience at its internal centre the true static pressure of the wind, and hence to be suitable for tapping and connection with a gauge intended to show the true pressure, whatever the angle of impact against its exterior. The writer cannot endorse this claim, for the aërodynamic reason that when a circular disc encounters a current at a sufficiently large angle of incidence its entire periphery is subject to suction; hence in the case of the sandwich there must, for such angle, be a deficit of true static pressure all over its interior.

The infinitude of practical devices which can be constructed in some way involving the foregoing considerations may be divided into two general classes: those placing the barograph in a stream-line case having on the outer surface some neutral area which can be perforated to transmit inwardly the true pressure; those having a true-pressure nozzle, or collector, suitably connected with the barograph case, wherever it may be placed.

FIG. 3.

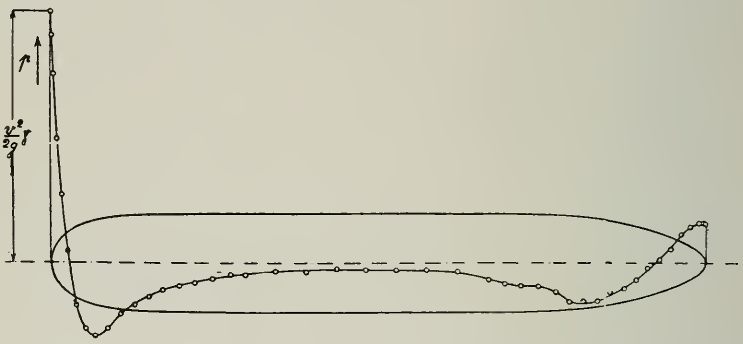


Air-pressure distribution on balloon model moving large end first. Minimum pressure toward stern. Ordinates represent air pressure.

For example, the accompanying figures (Figs. 3 and 4), taken from Fuhrmann's paper on pressure distribution on balloon models, show a form which, in a uniform current, is fairly suitable for either a barograph case or a pressure nozzle connected therewith by suitable tubing. As the distance of the dots from the axial line of the diagram of the models indicates the excess or deficit of pressure on the corresponding parts of the surfaces, it is seen, by scaling the diagram, that the mid or aft regions of the surfaces have pressure which, if not actually zero, differ from the true static pressures of the wind by less than five per cent. of that shown at the point of the prow, where it is always a maximum. The true-pressure case, or nozzle, would, of course, have to be placed before the aëroplane far enough to avoid the pressure disturbance caused by the flier itself. Doubtless still better forms for the purpose in hand could be found for a current of varying direction, by experiment in a wind tunnel, and this might form a suitable task for some college student of physics or engineering.

The foregoing inquiry was prompted by a former chairman of the Contest Committee of the Aëro Club of America, who wished to know how to avoid or evaluate the errors of an aëroplane barograph caused by the rush of air past his instrument case. Having indicated how to avoid or minimize the errors, we may now attempt to evaluate them for certain conditions. Assuming the worst possible condition, let the barograph case set squarely to the wind, and have an ample perforation in the centre of its front face. Then, as is well known in fluid dynamics, the excess of pressure inside the case will be that due to a vertical column of homogeneous air of a height equal to the "velocity head," or height to which the aëroplane, as a projectile in vacuo, would rise vertically with its actual speed. This height is the greatest altitude error the instrument can make in such manner; and it is not inconsiderable.[2] For, if the speed of flight be sixty miles an hour, the velocity head is about forty yards; and if the speed be twice this, the head is four times forty yards, since the head increases as the square of the velocity.

Fig. 4.



Air-pressure distribution on balloon model moving large end first. Minimum pressure at sides. Ordinates represent pressures on corresponding parts of surface.

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[2] By suitably locating an aperture on the side of a model, suction intensities exceeding in numerical magnitude the "velocity head" have been found by some experimenters.

Under these conditions, if the barograph record be read when the aëroplane is flying at any altitude, and again when resting at the same altitude, the readings will indicate that the machine in flight was lower than when at rest, though both altitudes were identical; or, in particular, if an aëroplane having a speed of sixty miles an hour should rise to a height of fifty yards above the place where its stationary zero trace began, its barograph would indicate an altitude increment of ten yards instead of fifty. But this error could be obviated by taking the zero trace in full flight at a known level, providing the speed be the same at both levels.

Owing to the difference of speed of an aëroplane at two vastly different levels, the barograph errors at the two levels, due to the air rush, do not cancel each other. At a given angle of flight, as is well known, the square of the speed of sustentation varies inversely as the density; and, therefore, the velocity head, which varies as the square of the speed, must vary inversely as the density. Hence the errors in the altitude records at the two levels are inversely as the densities. If, for example, the sea-level speed of a machine be sixty miles an hour, the error in the altitude record will be forty yards at that level and fifty yards up where the density is eighty per cent. of that at the sea-level. The differential error is thus ten yards for the difference of the two levels, which is slightly over one mile, as indicated by meteorological tables. But this is the maximum error for that altitude change. If the barograph case were given a more favorable orientation the error would be much less. And if it were placed inside a shield of the balloon model form here shown, the differential error would, if not actually zero, be less than five per cent. of ten yards, or, say, a half of one yard. Compared with the barograph errors due to fatigue and other causes, this item should not greatly perturb even a conscientious chairman of an aëronautic contest committee.

January, 1913.

Aeroplanes in Warfare. ANON. (*Sci. Amer.*, cvii, 19, 402.)—A number of aëroplanes were used with great success by the Italians in their war in Tripoli. On August 24, 1912, Lieutenant Manzini fell into the Mediterranean and was drowned while reconnoitring. Turkey has more than a dozen officer aviators, who have learned to fly in England and France. They use Bristol, Blériot, and R. E. P. monoplanes and Farman biplanes. The Servian army has three aviators, with machines of the Blériot type; and the Roumanian and Bulgarian armies have strong forces of aviators with various types of aëroplanes. There are several good Montenegrin military aviators, and the Greek officers who learned at the Farman school in France are excellent flyers. The Bulgarian army has more than six Bristol monoplanes, while at the Roumanian army manœuvres, Mr. C. H. Pixton made some good demonstration flights with one of these English machines. Ten Italian and Russian aviators, including Abramovitch (who recently flew from Berlin to St. Petersburg) and Nicholas Popoff, were engaged by the Servians and Bulgarians to scout for the allied armies. The two Russians used Wright biplanes. Popoff made several flights in the vicinity of Adrianople, and while soaring over this besieged city was struck by a shrapnel shell and fell to his death. A Farman biplane was used by the Greeks for scouting before the invasion of Turkey was decided upon, and a radius of fifty miles of country was flown over.

Hydraulic Lime. G. HENTSCHEL. (*Tonind. Zeit.*, xxxvi, 1843.)—In calculating the hydraulic modulus

$$\frac{CaO + MgO}{SiO_2 + R_2O_3}$$

of a sample of hydraulic lime, any undecomposed calcium carbonate and insoluble silica must be taken into consideration by subtracting the amount of lime combined with carbon dioxide, and the amount of silica which is not soluble, from the respective constituents as they appear in the formula. The nearer its hydraulic modulus approximates to that of Portland cement (1.7 to 2.1), and the smaller the amounts of insoluble residue and calcium carbonate which it contains, the greater is the value of a hydraulic lime. It was found that by raising the temperature of calcination, so as to decompose the calcium carbonate completely without dead-burning the lime, a stronger-setting hydraulic lime was obtained, yielding sand-mortars which had 2½ times the crushing strength of sand-mortars prepared from the same raw materials calcined at a lower temperature. The addition of 2 per cent. of stucco plaster, or of 2½ per cent. of raw gypsum, greatly increased the crushing strength of hydraulic lime mortars, especially when these were exposed to atmospheric conditions only.

RECENT DEVELOPMENTS IN STEAM TURBINES.*

BY

H. T. HERR,

Vice-President and General Manager, The Westinghouse Machine Company.

XXVII. The following formula, a proof of which will be given later, serves to calculate the extent to which condensation takes place during adiabatic expansion, and so allows the relation of pressure to volume to be determined.

Before expansion, let the initial dryness of the steam be q_1 and its absolute temperature T_1. Then if it expands adiabatically until its temperature falls to any value T, its dryness after expansion is

$$q = \frac{T}{L}\left(\frac{q_1 L_1}{T_1} + \log_e \frac{T_1}{T}\right)$$

L_1 and L are the latent heats (in thermal units) of one pound of steam before and after expansion respectively. When the steam is dry to begin with, $q_1 = 1$.

This formula, which is applicable, with proper values of L, to any vapor, may be called the equation of adiabatic expansion or compression. It does not directly give the relation of pressure to volume, but it allows the dryness at any stage of the process to be calculated, and from that (together with the fact that the part which remains in the condition of vapor is saturated) it is easy to find the volume which the mixture will fill when its pressure has changed to any assigned value.

Suppose, for instance, that originally dry saturated steam at an absolute pressure of 115.1 pounds per square inch is made to expand adiabatically. Its original volume per pound is 3.843 cubic feet, and its temperature is 338° Fahr. To find the relation of pressure to volume at any stage in expansion: Take any value of the pressure reached by expansion, say 20.8 pounds per square inch absolute. The expanded temperature is 230° Fahr. by steam tables. This gives the values of quantities in the adiabatic equation above:

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* Continued from page 412.

$q_1 = 1$

$T_1 = 338 + 461 = 799$

$T = 230 + 461 = 691$

$L_1 = H_1 - h_1 = 1185 - 308.7 = 876.3$

Hence, $$q = \frac{691}{953.4} \frac{1 \times 876.3}{799} + \log_e \frac{799}{691} = 0.9$$

$v = qV + (1 - q)\,w$

$V = 19.18$ cubic feet from the steam tables

$v = .9 \times 19.18 + .1 \times .017 = 17.26$

Since $w = .017$ cubic foot

Wet steam follows approximately the law expressed by the equation $pv^n =$ constant where n varies directly as q, as illustrated in the following table:

$q = 1$	.95	.9	.85	.80	.75	.7
$n = 1.135$	1.13	1.125	1.12	1.115	1.11	1.105

XXVIII. To deduce the expression for the work done by Carnot's engine using steam for a working substance, let it be

FIG. O.

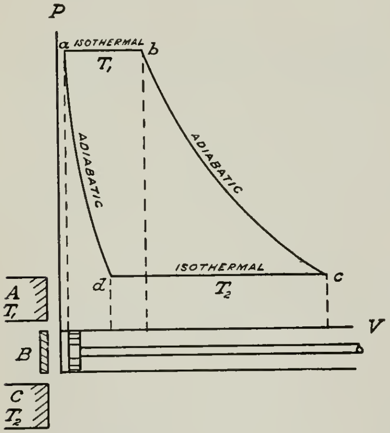
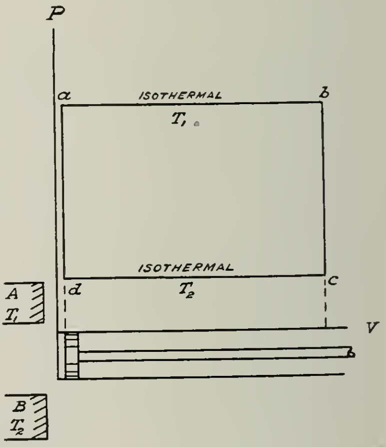


FIG. P.



supposed that Fig. O represents, as before, a long cylinder composed of non-conducting material, except the head, and fitted with a non-conducting piston; also an indefinite source of heat A at some temperature T_1. A receiver of heat or a condenser C at some lower temperature T_2, also a non-conducting cover B. Suppose the cylinder contains one pound of water to begin with, at temperature T_1:

(1) Apply A to the end of the cylinder and allow the piston to move outward under constant pressure p_1, which corresponds to the temperature T_1. The water will take in heat and be converted into steam, expanding isothermally at temperature T_1. This part of the cycle is represented on the diagram Fig. O by the line $a - b$.

(2) Remove A and apply B. Allow expansion to continue adiabatically with falling pressure until the temperature falls to T_2. The pressure will then be p_2, corresponding in the steam table to T_2, which is the temperature of the cold body C. This adiabatic expansion is plotted in the figure by the curve $b - c$.

(3) Remove B and apply C and compress. Steam is condensed by the rejection of heat to C. The action is isothermal, and the temperature remains T_2. Let this be continued until a certain point d is reached, after which adiabatic compression will complete the cycle.

(4) Remove C and apply B. Continue the compression, which is now adiabatic. If the point d has been properly chosen, the cycle will be completed by restoring the working fluid to the state of water at temperature T_1.

Since the process is reversible, and since heat is taken in only at T_1 and rejected only at T_2, the thermal efficiency is

$$e = \frac{T_1 - T_2}{T_1} = \frac{W}{Q}$$

Therefore $$W = Q\left(\frac{T_1 - T_2}{T_1}\right)$$

There are in the process $q_b - q_a$ pounds of water turned into steam; therefore, the amount of heat supplied is equal to

$$L_1 (q_b - q_a)$$

Substituting in the above equation this value for Q:

$$W = L_1 \frac{(q_b - q_a)(T_1 - T_2)}{T_1}$$

If the action so described could be realized in practice, an ideally perfect steam engine using saturated steam could be constructed. Like any other perfect heat engine, an engine of this kind has an efficiency depending upon the temperatures between which it works, and upon nothing else. The fraction of the heat supplied to it, which such an engine could convert into useful work, would depend simply on the two temperatures, and therefore on the pressures at which steam was produced and condensed respectively.

The temperature of condensation is limited by the consideration that there must be an abundant supply of some substance to absorb the rejected heat. Water is generally used for this purpose, so that T_2 has for its lower limit the temperature of the available water supply. The higher temperature T_1 and pressure p_1 are limited in a practical way to the strength of materials and ability to operate an engine under high temperature and pressure conditions. A steam engine under the most favorable circumstances comes very far short of taking full advantage of the high temperature at which heat is produced in the combustion of coal, because steam pressures in boilers are generally kept somewhere within 200 to 250 lbs. per square inch, the temperature of the steam corresponding to this pressure being somewhere in the neighborhood of 400° Fahr. From a thermodynamic standpoint, the worst thing about a steam engine is the irreversible drop of temperature between the furnace and the boiler. The combustion of fuel supplies heat at a high temperature, but a great part of the convertibility of that heat into work is sacrificed by the fall in temperature which is allowed to take place before the conversion into work begins.

If the temperature of condensation be taken at 60° Fahr. as a lower limit, the efficiency of a perfect steam engine using saturated steam would depend on the value of the absolute pressure of production of steam as follows:

P_1 in pounds per square inch.......	40	80	120	160	200
Highest ideal efficiency............	.284	.326	.350	.368	.381

As a contrast to the ideally perfect steam engine, consider the cyclic process occurring in the early engines of Newcomer in which steam is used non-expansively, or rather such a process as would have occurred if the engine had its cylinder made of a perfect non-conductor of heat and other conditions as recited in the description of Carnot's cycle.

Referring to Fig. P:

(1) Apply the hot body A and evaporate the water as before at pressure P_1 $(a - b)$. Heat taken in per pound of the working fluid $= L_1$.

(2) Remove A and apply the cold body C. This at once condenses the steam and reduces the pressure to $P_2(b - c)$.

(3) Compress at P_2 in contact with C until condensation is complete and water at T_2 is left $(c - a)$.

(4) Remove C and apply A. This heats the water again to T_1 and completes the cycle. Heat taken in $= h_1 - h_2$. Here the action is not reversible.

To calculate the efficiency:

$$\frac{\text{Work done}}{\text{Heat supplied}} = \frac{(P_1 - P_2)\,(V_1 - w)}{J(L_1 + h_1 - h_2)}$$

The values of this equation will be found to range from .067 to .072 for the values of P_1 stated above for Carnot's cycle when the temperature of condensation is 60° Fahr.

FIG. Q.

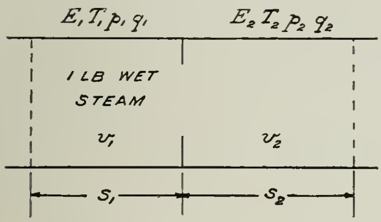
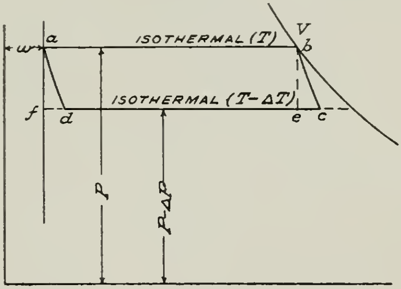


FIG. R.



The efficiency of an actual Newcomer engine is much lower than the figures given, because in every stroke of the piston a large part of the steam entering the cylinder is at once condensed upon the sides and the volume of steam supplied by the boiler was therefore much greater than the piston displacement.

XXIX. When steam is passed through a small orifice, it is sometimes unable to get through fast enough to keep up the pressure on the other side. There is, consequently, a drop in pressure and the steam is said to be throttled. When such a condition takes place in a closed vessel or a pipe through which steam is flowing, the steam is said to be throttled or wire-drawn.

Let Fig. Q represent a pipe of perfect non-conducting material with a restriction through which one pound of wet steam flows with energy E_1, temperature T_1, pressure p_1, quality q_1, volume v_1, and let the state of this one pound of wet steam after passing through the orifice be represented by energy E_2, temperature T_2, pressure p_2, quality q_2, volume v_2, and let p_1, p_2, and q_1 be known quantities, then T_1 and T_2 are known from the steam tables.

From the first equation of thermodynamics:

$$E_2 - E_1 = - W'' + W' + Q$$

but,

$$Q = 0$$

(since the pipe is a non-conductor of heat and any heat caused by friction of flow of the steam goes back into steam).

Let $A =$ the area of a cross section of the pipe and s_1, s_2 the length of the pipe which the one pound of steam at the pressures and volumes specified would occupy; then,

$$W'' = (p_2 A)s_2 = p_2 v_2$$
$$W' = (p_1 A)s_1 = p_1 v_1$$
$$\left.\begin{aligned} E_2 &= E_{32} - p_2(v_2 - w) + J(h_2 + q_2 L_2) \\ E_1 &= E_{32} - p_1(v_1 - w) + J(h_1 + q_1 L_1) \end{aligned}\right\} \text{See XXIII.}$$

Subtracting,

$$E_2 - E_1 = - p_2 v_2 + p_2 w + J(h_2 + q_2 L_2) + p_1 v_1 - p_1 w, - J(h_1 + q_1 L_1)$$

But,

$$E_2 - E_1 = - W'' + W' = - p_2 v_2 + p_1 v_1$$
$$\therefore - p_2 v_2 + p_1 v_1 = - p_2 v_2 + p_2 w + J(h_2 + q_2 L_2) + p_1 v_1$$

Cancelling and solving for q_2,

$$q_2 = \frac{q_1 L_1 + h_1 - h_2 + \dfrac{(p_1 - p_2)w}{J}}{L_2}$$

But, $p_1 - p_2$ is very small, also w is very small.

Therefore the product of these two small quantities will be so small that it may be neglected.

$$\therefore q_2 = \frac{q_1 L_1 + h_1 - h_2}{L_2},$$

which is the expression for the dryness of steam after throttling.

To show that the dryness is greater after throttling than before,

$$q_2 = \frac{q_1 L_1 + h_1 - h_2}{L_2}$$

Adding q_1L_2 and subtracting q_1L_2 to and from the second member of the above equation,

$$q_2 = \frac{q_1L_2 - q_1(L_2 - L_1) + h_1 - h_2}{L_2} = q_1 + \frac{h_1 - h_2 - q_1(L_2 - L_1)}{L_2}$$

But,

$$H_1 > H_2, \text{ because } p_1 > p_2$$
$$\therefore h_1 + L_1 > h_2 + L_2$$
$$h_1 - h_2 > L_2 - L_1$$
$$\therefore h_1 - h_2 > q_1(L_2 - L_1)$$

since $q_1 < 1$

$$\therefore q_2 = q_1 + (\text{some positive number})$$
$$\therefore q_2 > q_1$$

XXX. As pointed out in Carnot's cycle, an ideally perfect steam engine gives an indicator diagram with two lines of uniform pressure (isothermal) connected by two adiabatic curves. The heat taken in was L per pound of working substance, and, since the engine was reversible, its efficiency was

$$\left(\frac{T_1 - T_2}{T_1}\right)$$

from which it follows that the work done or area of the diagram was

$$L\left(\frac{T_1 - T_2}{T_1}\right)$$

To show how the volume of one pound of dry saturated steam may be calculated, let the engine operate between two temperatures which differ by only a very small amount. We may call these temperatures T and $T - \triangle T$. The indicator diagram is represented by Fig. R.

Since the process in Fig. R is assumed to be a Carnot cycle, and consequently reversible,

$$e = \frac{W}{Q''} = \frac{T_1 - T_2}{T_1} = \frac{T - (T - \triangle T)}{T} = \frac{\triangle T}{T}$$
$$Q'' = JL$$

From Fig. R,

$$W = a\,b\,c\,d = a\,f\,b\,e - a\,f\,d + b\,e\,c = \triangle P\,(V - w) - a\,f\,d + b\,e\,c$$

Suppose $e\,c$ greater than $f\,d$, then $e\,b\,c$ is less than $\triangle P(ec)$ and $f\,d\,a$ is less than $\triangle P(ec)$.

Subtracting these inequalities,

$$e\,b\,c - f\,d\,a < \triangle P\,(ec)$$
$$\therefore W = \triangle P\,(V - w)$$

with error less than $\triangle P\,(ec)$

But,

$$W = eQ'' = \frac{\triangle T}{T} JL$$

Substituting,

$$\triangle P\,(V - w) = \frac{\triangle T}{T} JL \text{ with error less than } \triangle P(ec).$$

Divide by $\triangle P$.

$$V - w = \frac{JL}{T} \frac{\triangle T}{\triangle P} \text{ with error less than } (ec).$$

Let $\triangle P$ approach zero as a limit, then,

$$V - W = \frac{JL}{T} \frac{dT}{dP} \quad .$$

$\frac{dT}{dP}$ is the rate at which the temperature of saturated steam alters relatively to the pressure when the temperature is T. Thus, $V - w = \frac{JL}{T} \frac{dT}{dP}$ is a means of calculating the volume of one pound of steam when the values of L and of $\frac{dT}{dP}$ are known.

Reanault's experiments have determined L, and by giving the relation of P to T, they have also given data from which it is easy to find $\frac{dT}{dP}$ either by measuring the slope of the tangent to the curve of P and T or by differentiating a formula such as

$$\log P = 6.1007 - \frac{2732}{T} - \frac{396945}{T},$$

which expresses the experimental relation between these two quantities. It is in this way that values of V in steam tables have been determined, and the advantage of the method is that L and $\frac{dT}{dP}$ can be measured more accurately than V could itself be measured, and thus the values of V obtained indirectly from them are more likely to be right than those obtained by direct experiment.

The formula shows that the numbers found in this way depend on J and are nearly proportional to it, since w is small.

XXXI. To show that $\frac{Q}{T}$ for any two isothermals between the same two adiabatics is the same, let Fig. S plot the process of two isothermals between the two adiabatic curves as shown, and let T_1 represent the absolute temperature at the beginning of the cycle at a and along the isothermal $a - b$. Let T_2 represent the absolute temperature along the second isothermal $c - d$, both isothermals being intercepted by the adiabatics $a - d$ and $b - c$. In passing from a to b the substance takes in heat during the operation $= Q_1$. In passing from c to d heat is rejected to the amount Q_2, or *vice versa* taken in from d to c.

FIG. S.

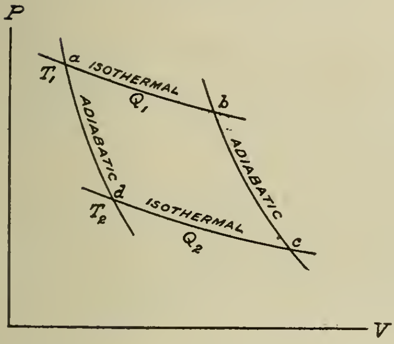
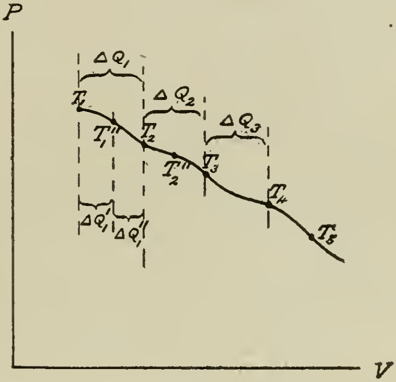


FIG. T.



In the adiabatics $b - c$ and $d - a$ heat is neither taken in nor rejected. The efficiency of the process is the ratio:

$$\frac{\text{Heat converted into work}}{\text{Heat supplied}} = \frac{Q'' - Q'}{Q''} = \frac{T_1 - T_2}{T_1}$$

But

$$Q'' = Q_1 \text{ and } Q' = Q_2$$

$$\therefore \frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$$

$$1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\therefore \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

or

$$\frac{Q_2}{T_2} = \frac{Q_1}{T_1}$$

Hence $\frac{Q}{T}$ for any two isothermals between the same two adiabatics is the same.

XXXII. When a substance takes in or rejects heat in passing from one state to another, it may be considered to perform a process made up of the addition or rejection of heat in quantities bearing some relation to the absolute temperatures at which heat is taken in or rejected.

A summation of these amounts of heat at their respective absolute temperatures may be written: limit $\Sigma \frac{\triangle Q}{T}$ (*i.e.*, limit of the sum of such terms as $\frac{\triangle Q}{T}$).

To explain what is meant by limit $\frac{\triangle Q}{T}$, and to find two quantities between which it lies in certain cases, let Fig. T represent by the curve the process by which any substance, whose laws are known, changes its state.

Let the process be divided into a number of divisions in which T_1, T_2, T_3, T_4, etc., are the absolute temperatures at which amounts of heat $\triangle Q_1$, $\triangle Q_2$, $\triangle Q_3$, $\triangle Q_4$, etc., are taken in or rejected.

Assume that the initial divisions are five in number.

Let S represent the sum of such terms as $\frac{\triangle Q}{T}$. Then

$$S' = \frac{\triangle Q_1}{T_1} + \frac{\triangle Q_2}{T_2} + \frac{\triangle Q_3}{T_3} + \text{etc.} = \Sigma_5 \frac{\triangle Q}{T}$$

Divide each division in the process into two parts. Then

$$S'' = \frac{\triangle Q_1'}{T_1} + \frac{\triangle Q_1''}{T''} + \frac{\triangle Q_2'}{T_2} + \frac{\triangle Q_1''}{T_2''} + \text{etc.} = \Sigma_{10} \frac{\triangle Q}{T}$$

Again divide each part into two. Then

$$S''' = \Sigma_{20} \frac{\triangle Q}{T}$$

$$\triangle Q_1 = \triangle Q_1' + \triangle Q_1''$$

But $\frac{\triangle Q_1' + \triangle Q_1''}{T_1}$ is not equal to $\frac{\triangle Q_1'}{T_1} + \frac{\triangle Q_1''}{T_1''}$

By taking the divisions small enough the error can be made as small as we please, and by going to the limit:

$$S = \text{limit}\ \Sigma \frac{\triangle Q}{T} = \Sigma \frac{dQ}{T}\cdot$$

If in the diagram Fig. T we let the greatest temperature from the beginning of the process be T_G and the lowest T_L, the following inequalities result, when all the $\triangle Q$'s are positive:

$$\frac{\triangle Q_1}{T_G} \ngtr \frac{\triangle Q_1}{T_1} \ngtr \frac{\triangle Q_1}{T_L}$$
$$\frac{\triangle Q_2}{T_G} \ngtr \frac{\triangle Q_2}{T_2} \ngtr \frac{\triangle Q_2}{T_L}$$

and so on for any number of terms.

Adding these inequalities:

$$\frac{1}{T_G}(\triangle Q_1 + \triangle Q_2 + \triangle Q_3 + \text{etc.}) \ngtr \Sigma\frac{\triangle Q}{T} \ngtr \frac{1}{T_L}(\triangle Q + \triangle Q + \triangle Q + \text{etc.})$$

$$\therefore \frac{Q}{T_G} \ngtr \Sigma\frac{\triangle Q}{T} \ngtr \frac{Q}{T_L}$$

Increasing the number of divisions indefinitely:

$$\frac{Q}{T_G} \ngtr \text{limit}\,\Sigma\frac{\triangle Q}{T} \ngtr \frac{Q}{T_L}$$

For isothermal expansion or compression:

$$T_L = T = T_G$$

$$\therefore \frac{Q}{T} \ngtr \text{limit}\,\Sigma\frac{\triangle Q}{T} \ngtr \frac{Q}{T}$$

$$\therefore \text{limit}\,\Sigma\frac{\triangle Q}{T} = \frac{Q}{T}\text{ for isothermal.}$$

In adiabatic expansion or compression:

$$Q = 0$$

$$\therefore 0 \ngtr \text{limit}\,\Sigma\frac{\triangle Q}{T} \ngtr 0$$

$$\therefore \text{limit}\,\Sigma\frac{\triangle Q}{T} = 0 \text{ for adiabatic expansion or compression.}$$

XXXIII. Proof that the limit $\Sigma\frac{\triangle Q}{T}$ is the same for any two processes between the same two states:

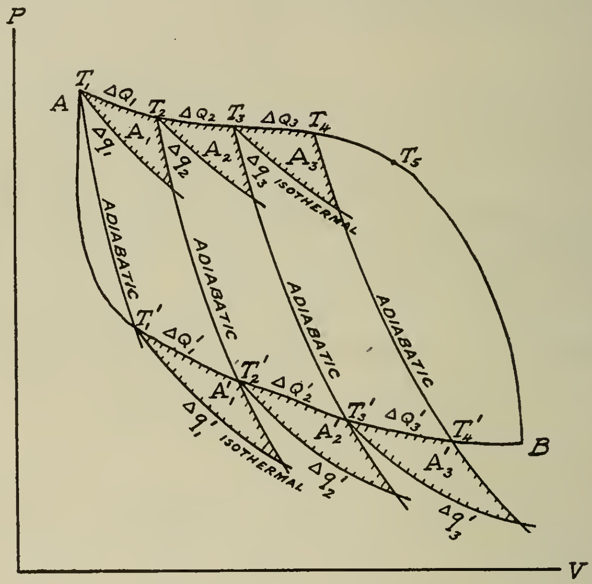
Let Fig. U represent a pressure volume diagram for any substance with the two processes as shown between the two states A and B.

To prove

$$\left(\begin{array}{c}\text{limit } \Sigma \frac{\Delta Q}{T} \\ \text{of} \\ \text{upper curve}\end{array}\right) = \left(\begin{array}{c}\text{limit } \Sigma \frac{\Delta Q}{T} \\ \text{of} \\ \text{lower curve}\end{array}\right)$$

Divide the upper curve into parts in which ΔQ_1, ΔQ_2, etc., will represent heat taken in or rejected at temperatures T_1, T_2, T_3, etc., and through these divisions pass adiabatic lines intersecting the lower curve as shown and dividing it at T'_1, T'_2, T'_3, etc., with heats $\Delta Q'_1$, $\Delta Q'_2$, $\Delta Q'_3$, etc., respectively.

FIG. U.



Through T_1, T_2, T_3, etc., T'_1, T'_2, T'_3, etc., pass isothermals intersecting the adiabatics and curves A B as shown, and let Δq_1, Δq_2, etc., and $\Delta q'_1$, $\Delta q'_2$, etc., represent the heats taken in or rejected for these isothermals respectively, and let A_1, A_2, A_3, etc., A'_1, A'_2, A'_3, etc., represent the respective areas of the small triangles comprehended between the curves A B and the adiabatics and isothermals. Take any small triangular curve such as represented on an enlarged scale (Fig. V).

Since Fig. V is a closed curve, it represents a cyclic process:

Hence $W = Q$

But $Q = \triangle Q_3 + 0 - \triangle q_3$

$$\therefore W = A_3 = \triangle Q_3 - \triangle q_3$$

$$\therefore \triangle Q_3 = A_3 + \triangle q_3$$

Divide by T_3

$$\frac{\triangle Q_3}{T_3} = \frac{\triangle q_3}{T_3} + \frac{A_3}{T_3}$$

Similarly,

$$\frac{Q'_3}{T'_3} = \frac{q'_3}{T'_3} + \frac{A'_3}{T'_3}$$

Subtracting the latter from the former:

$$\frac{\triangle Q_3}{T_3} - \frac{\triangle Q'_3}{T'_3} = \frac{\triangle q_3}{T_3} - \frac{\triangle q'_3}{T'_3} + \frac{A_3}{T_3} - \frac{A'_3}{T'_3}$$

FIG. V.

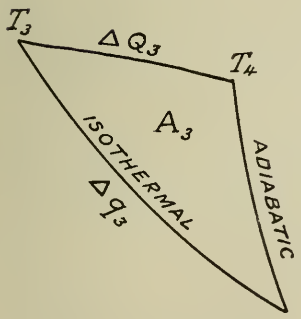
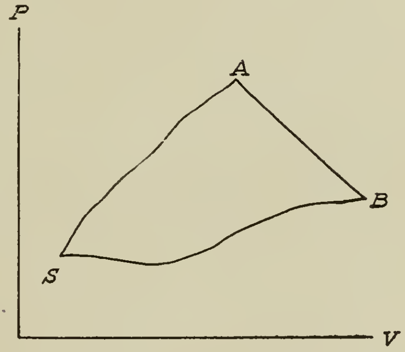


FIG. W.



But from XXXI,

$$\frac{\triangle q_3}{T_3} - \frac{\triangle q'_3}{T'_3} = 0$$

$$\therefore \frac{\triangle Q_3}{T_3} = \frac{\triangle Q'_3}{T'_3} + \frac{A_3}{T_3} - \frac{A'_3}{T'_3}$$

Performing the same process for each division and adding all together:

$$\left(\begin{matrix}\Sigma\frac{\triangle Q}{T}\\ \text{upper}\\ \text{curve}\end{matrix}\right)=\left(\begin{matrix}\Sigma\frac{\triangle Q_1}{T}\\ \text{lower}\\ \text{curve}\end{matrix}\right)+\left(\begin{matrix}\Sigma\frac{A}{T}\\ \text{upper}\\ \text{curve}\end{matrix}\right)-\left(\begin{matrix}\Sigma\frac{A_1}{T}\\ \text{lower}\\ \text{curve}\end{matrix}\right)$$

Taking an infinitely large number of divisions:

$$\left(\begin{matrix}\text{limit }\Sigma\frac{\triangle Q}{T}\\ \text{of}\\ \text{upper curve}\end{matrix}\right)=\left(\begin{matrix}\text{limit }\Sigma\frac{\triangle Q}{T}\\ \text{of}\\ \text{lower curve}\end{matrix}\right)$$

$\therefore$ the limit $\Sigma\frac{\triangle Q}{T}$ is the same for any two processes between the same two states.

XXXIV. When a substance takes in or rejects heat, it is said to change its entropy, the change of entropy being defined by the expression:

$$\text{limit }\Sigma\frac{\triangle Q}{T}\text{ or }\Sigma\frac{dQ}{T},$$

each dQ of the heat taken in or rejected being divided by the absolute temperature which the substance had at the time.

In dealing with entropy, just as in dealing with total heat, it is convenient to choose some arbitrary starting point and reckon the entropy from that point as a zero.

Thus in reckoning the entropy of steam at any temperature the condition of water at 32° Fahr. may be taken as a convenient datum and calculate $\Sigma\frac{dQ}{T}$ from that, calling the value so calculated the entropy of steam.

Entropy is usually denoted by ϕ, and in giving it numerical values it is to be calculated per unit mass of the substance considered.

From this definition and what has preceded, it is evident that when a substance is going through an adiabatic process its entropy does not change, since heat is neither added to nor taken from the substance. Also, in a cyclic process $\Sigma\frac{dQ}{T}=0$ when the whole cycle is considered. Hence, when the cycle is completed the entropy of the substance, as well as its pressure, temperature, volume, and initial energy, was returned to the value which it had at the beginning of the cycle.

Just as isothermal lines are lines of uniform temperature, so adiabatic lines are lines of uniform entropy, and just as isothermals can be distinguished by numbers T_1, T_2, etc., denoting the particular temperature for which each is drawn, so adiabatics can be distinguished by numbers ϕ_1, ϕ_2, etc., denoting the particular value of the entropy of each. From this point of view adiabatics are often called isentropic lines.

In Fig. W let S represent the standard state of a substance, which for water is usually taken at 32° Fahr., as explained above.

Let any other state of the substance be represented by A and calculate:

limit $\Sigma \frac{\Delta Q}{T}$ for SA. Then the entropy of $A = \phi_A = \text{limit} \sum_{SA} \frac{\Delta Q}{T}$

Take any other state of the substance, such as B:

Then $\phi_B = \text{limit} \sum_{SB} \frac{\Delta Q}{T}$ = entropy of B.

But from XXXIII,

$$\phi_B = \text{limit} \sum_{SB} \frac{\Delta Q}{T} = \text{limit} \sum_{SA} \frac{\Delta Q}{T} + \text{limit} \sum_{AB} \frac{\Delta Q}{T} = \phi_A + \text{limit} \sum_{AB} \frac{\Delta Q}{T}$$

$$\therefore \phi_B - \phi_A = \text{limit} \sum_{AB} \frac{\Delta Q}{T}$$

Hence the difference in entropy between any two states of a substance is equal to the limit $\Sigma \frac{\Delta Q}{T}$ between these two states, irrespective of the process between the two states.

If in Fig. W the process between A and B is adiabatic, the limit $\sum_{AB} \frac{Q}{T}$ is zero, and hence in adiabatic expansion or compression $\phi_B = \phi_A$, or the entropy is constant.

XXXV. The change of state of a substance may be plotted on a diagram having absolute temperatures for ordinates and entropy for abscissæ, just as such processes are plotted on the pressure volume diagram. Such diagrams are called temperature-entropy diagrams, and are governed by the following principles:

First Principle.—To every point on the PV diagram there corresponds one, and only one, point on the ϕT diagram.

Second Principle.—To a cyclic process on the PV diagram there corresponds a closed curve on the ϕT diagram.

Third Principle.—To every point on the ϕT diagram there corresponds one, and only one, point on the PV diagram.

Fourth Principle.—An isothermal on the ϕT diagram is a horizontal line.

Fifth Principle.—An adiabatic on the ϕT diagram is a vertical line.

Sixth Principle.—On the ϕT diagram the heat supplied is represented in the same way as the work done is represented on the PV diagram, viz., by the area under the curve.

XXXVI. The efficiency of Carnot's cycle may be verified by means of the ϕT diagram as follows:

FIG. X.

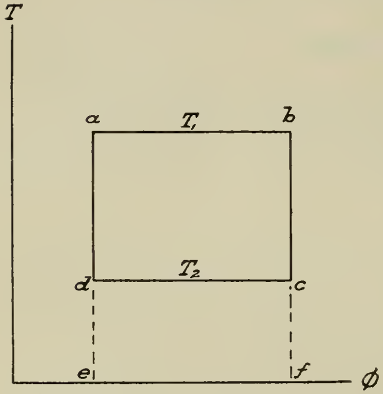
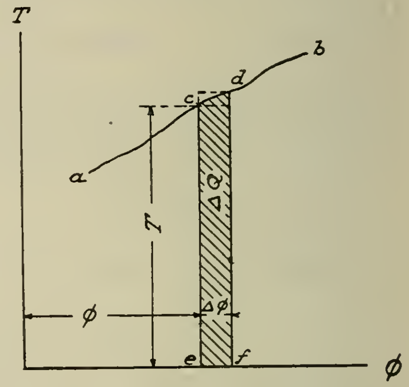


FIG. Y.



In Fig. X let $a\,b\,c\,d$ represent a Carnot cycle in which $a\,b$ is the isothermal expansion, $b\,c$ the adiabatic expansion, $c\,d$ the isothermal compression, and $d\,a$ the adiabatic compression.

The efficiency in any engine is the ratio of the heat converted into work to the heat supplied, or

$$e = \frac{Q'' - Q'}{Q''}$$

From the figure,

$$Q'' = \text{area } a\,b\,f\,e\,a = T_1(\phi_b - \phi_a)$$
$$Q' = \text{area } d\,c\,f\,e\,d = T_2(\phi_b - \phi_a)$$

Subtracting and dividing by Q'' and its equivalent,

$$e = \frac{Q'' - Q'}{Q''} = \frac{T_1(\phi_b - \phi_a) - T_2(\phi_b - \phi_a)}{T_1(\phi_b - \phi_a)}$$
$$\therefore e = \frac{T_1 - T_2}{T_2},$$

which is the expression of the efficiency for a Carnot cycle.

XXXVII. Proof that the derivative of ϕ with respect to T is equal to $\frac{1}{T}$.

Let Fig. Y represent a ϕT diagram, plotting any process $a\,b$ as shown.

At any point on $a\,b$, such as c, the entropy will be ϕ and the temperature T.

At any other point adjacent to c on $a\,b$, such as d, the entropy will be $\phi + \triangle\phi$ and the temperature $T + \triangle T$.

From the figure,

$$\begin{aligned} e\,c &= T \\ e\,f &= \triangle\phi \end{aligned}$$

Also $\triangle Q$ is equal to the area under the curve from c to d.

$$\begin{aligned} &f\,d = T + \triangle T \\ &\triangle Q < (T + \triangle T)\triangle\phi \\ &\triangle Q > T(\triangle\phi) \\ &\frac{\triangle\phi}{\triangle Q} > \frac{1}{T + \triangle T} \text{ and } \frac{\triangle\phi}{\triangle Q} < \frac{1}{T} \end{aligned}$$

If the division cd is taken indefinitely small and $\triangle Q$ approaches zero as a limit,

$$\begin{aligned} &\frac{d\phi}{dQ} \nless \frac{1}{T} \text{ and } \frac{d\phi}{dQ} \ngtr \frac{1}{T} \\ &\therefore \frac{d\phi}{dQ} = \frac{1}{T} \end{aligned}$$

Therefore the derivative of the entropy with respect to the temperature is equal to $\frac{1}{T}$.

XXXVIII. Deduction of the expression for the entropy of water at any temperature:

Let w = the state of water at 32° Fahr., called the standard state. Assume one pound of water raised 1° Fahr., then, $Q = ms\,(t - 32^\circ) = t - 32^\circ$, since $m = 1$ pound and $s = 1$.

$$\begin{aligned} &\text{But, } t = T - 461. \\ &\therefore Q = T - 493. \end{aligned}$$

Taking the derivative of Q with respect to T—

$$\frac{dQ}{dT} = 1$$

$$\text{But, } \frac{d\phi}{dQ} = \frac{1}{T}$$

$$\frac{d\phi}{dT} = \left(\frac{d\phi}{dQ}\right)\left(\frac{dQ}{dT}\right) = \frac{1}{T}$$

$$\therefore \frac{d\phi}{dT} = \frac{1}{T} = \frac{d}{dT}(\log T) \text{ or}$$

$$\frac{d}{dT}(\phi - \log T) = 0$$

FIG. Z.

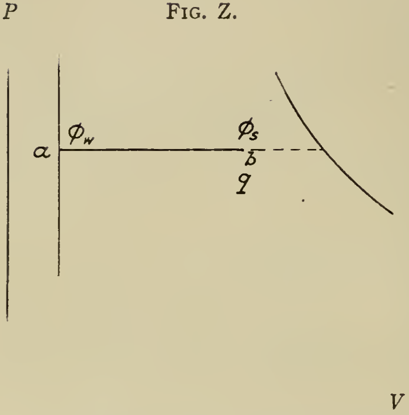
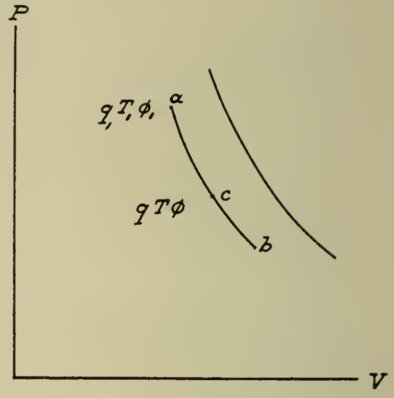


FIG. a.



If the derivative of a quantity is equal to zero, the quantity itself is equal to a constant.

$$\therefore \phi - \log T = K$$

When $T = 493$, $\phi = 0$ (since $493 = S$)

Substituting in the above—

$$K = -\log 493$$

Inserting this value of K—

$$\phi \text{ water} = \log T - \log 493 = \log \frac{T}{493},$$

which is the expression for entropy of water at any temperature.

XXXIX. Deduction of the expression for the entropy of wet steam of any dryness q and temperature T:

On the diagram Fig. Z let ϕ_w = entropy of water which is expanded isothermally from a to b, and let ϕ_s = entropy of the wet steam at b whose dryness is q.

From what has preceded—

$$\phi_s - \phi_w = \text{limit} \underset{ab}{\Sigma} \frac{Q}{T}$$

But ab is an isothermal,

$$\therefore \phi_s - \phi_w = \frac{Q}{T} = \frac{qL}{T}$$

$$\phi_s = \phi_w + \frac{qL}{T} = \log \frac{T}{493} + \frac{qL}{T}$$

$$\therefore \phi_s = \log \frac{T}{493} + \frac{qL}{T} = \phi_w + \frac{qL}{T},$$

which is the expression for the entropy of wet steam of any dryness q and temperature T.

If the steam be dry and saturated—

$$\phi_s = \log \frac{T}{493} + \frac{L}{T} = \phi_w + \frac{L}{T}$$

XL. Derivation of the adiabatic equation for wet steam:

Let Fig. *a* represent the PV diagram for the adiabatic expansion of wet steam plotted by the curve $a\ b$. Let the point a have dryness q_1, temperature T_1, and entropy ϕ_1.

Take any other point such as c on the curve $a\ b$ and let the dryness, temperature, and entropy be q, T, and ϕ respectively.

From XXXIX—

$$\phi_1 = \log \frac{T_1}{493} + \frac{q_1 L_1}{T_1}$$

$$\phi = \log \frac{T}{493} + \frac{qL}{T}$$

But $\phi_1 = \phi$, since the expansion is adiabatic.

$$\therefore \log \frac{T}{493} + \frac{qL}{T} = \log \frac{T_1}{493} + \frac{q_1 L_1}{T_1}$$

Transposing,

$$\frac{qL}{T} = \log \frac{T_1}{493} - \log \frac{T}{493} + \frac{q_1 L_1}{T_1}$$

$$\therefore q = \frac{T}{L}\left(\log \frac{T_1}{T} + \frac{q_1 L_1}{T_1}\right)$$

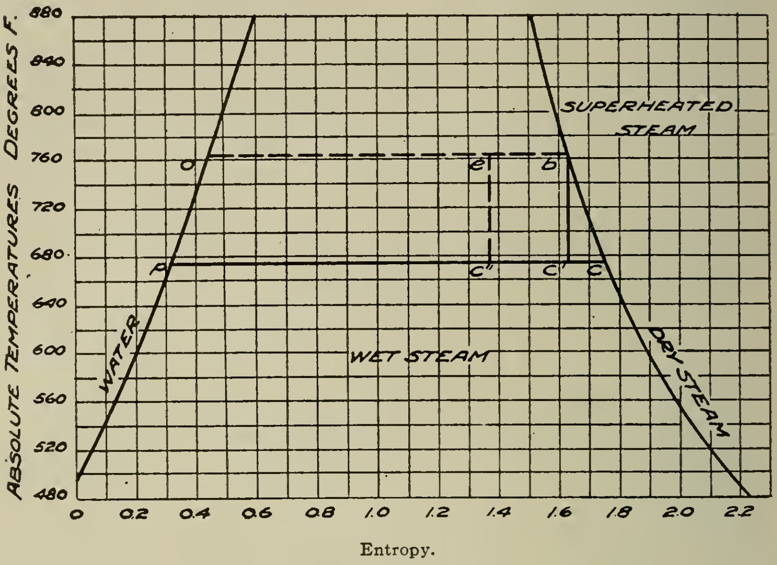
or

$$q = \frac{T}{L}\left(\frac{q_1 L_1}{T_1} + \log \frac{T_1}{T}\right)$$

which is the equation for the adiabatic expansion of wet steam.

XLI. In applying the entropy-temperature diagram to the investigation of particular cases in the expansion of steam, a chart showing the values of the entropy of water and steam is convenient as a reference. Such a chart is shown in Fig. *b*.

Fig. *b*.



The curve on the left marked "water" shows the relation of entropy to temperature before steam begins to form, while the curve on the right marked "steam" shows the same relation when all the water is converted into steam.

The horizontal distance between the two curves at any point, or $\phi_s - \phi_w$, represents the gain of entropy which occurs while the water is changing into steam, or $\frac{L}{T}$. An extension of the diagram to the left might be drawn in the form of a horizontal line at 32° F. to show the change of entropy when ice melts.

The values of the entropy on the diagram relate to 1 pound of water or steam reckoned from water at 32° Fahr.

From this diagram, together with the knowledge of the relation of pressure to volume in saturated steam, furnished by steam tables, it is easy to determine what proportion of water will be present at any state in adiabatic expansion or compression, and hence to draw the ordinary indicator diagram or pressure volume curve for an adiabatic process.

(*To be continued*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.[1]

THE DETERMINATION OF PHOSPHORUS IN STEELS CONTAINING VANADIUM.[2]

By J. R. Cain and F. H. Tucker.

In order to precipitate phosphorus quantitatively as phosphomolybdate from steels containing vanadium, it is necessary to reduce the latter to the quadrivalent state, otherwise precipitation is incomplete and there is contamination of the phosphomolybdate by vanadium. In the present method ferrous sulphate in slight excess is used as the reducing agent, and the following conditions should be observed:

(1) The temperature of precipitation should be held at a point (15° to 20°) where the nitric acid does not oxidize the excess of ferrous salt or the reduced vanadium before complete precipitation of phosphorus takes place; (2) the partial neutralization with ammonia, frequently used when phosphorus is precipitated as phosphomolybdate, must be made before reduction of the vanadic acid, otherwise the heat of neutralization causes the oxidation of most of the ferrous iron and reduced vanadium by the nitric acid; (3) care must be taken to prevent the action of oxides of nitrogen, formed by interaction of ferrous salt and nitric acid, on the reduced vanadium, since these substances seem to catalyze the oxidation of the vanadyl salt and may in some cases completely prevent precipitation of phosphorus, owing to the large amount of vanadic acid produced; (4) efficient means for shaking or agitation of the solutions in which precipitation is to take place must be provided.

The Bureau of Standards has prepared for early issue a circular concerning metallography in its wider sense. This is not restricted to the microscopical analysis alone. Thermal analysis, together with the correlation of physical properties with microscopical structure, thus find their place here.

The different methods of thermal analysis are briefly reviewed and compared. The importance that is attached to the metallographic method in the iron and steel industry is illustrated by a partial list of the more common applications in that field.

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[1] Communicated by the Bureau.

[2] Abstract of technologic paper.

The tests that the Bureau of Standards is equipped at present for carrying out are:

1. Thermal: Cooling and heating curves, melting points, heat treatment of alloys as specified.

2. Microscopical: Preparation of specimens and photomicrographs of specified magnification up to 1000 diameter (higher magnification by special arrangement), microscopical examination after special heat treatment.

3. Miscellaneous: Examination of metals after failure for evidence of the cause of failure, determination of various physical constants of metals and their temperature coefficients.

DEHYDRATION OF CLAYS.

A TECHNOLOGIC paper entitled "Dehydration of Clays," by G. H. Brown and E. T. Montgomery, of the Bureau, is ready for publication. The paper gives a review and statement of the results of experimental work upon the dehydration of clay. Among the main conclusions are the following:

All of the combined water of clay is not part of the clay base in the sense of water of hydration. For this reason clay cannot be said to possess a definite dehydration temperature. The combined water is expelled at comparatively low temperatures, so that even at 450° C. the bulk of it may be driven off. In heating clay to constancy in weight at different temperatures the velocity of the reaction is very slow at first and becomes suddenly rapid at 500°. The remaining portion of the water is removed more slowly and difficultly, so that a temperature of not less than 800° is required to accomplish complete expulsion.

The distinctness of the endothermal lag as well as the total loss in weight upon ignition (excluding abnormal loss due to carbon, sulphur, etc.) is a criterion of the purity of a clay. Likewise the thermal acceleration at about 850° is shown more clearly by the higher types of clay.

It has been shown that the clay substance of the impure clays represents a type essentially different from that of the purer materials, contrary to the generally-accepted view. A well-defined minimum is shown in the specific gravity curve of clays, located at approximately 500°.

Dehydration does not necessarily destroy the plasticity of clays, and hence the combined water appears to have no direct connection with the phenomenon of plasticity. Shales are least affected by heating within the dehydration temperature range, and, in fact, seem to be improved in plastic working behavior after preheating to about 500°. The surface clays examined lose their plasticity at the lowest temperatures, about 400°, followed by ball clay at 450°, kaolin 500°–600°, No. 2 fire clays 600°–750 °, and shales 750 °–800 °.

It was likewise shown that the presence of organic compounds cannot be a primary cause of plasticity, since these are oxidized in an atmosphere of pure air at about 500°. It was shown quite clearly that drying shrinkage is not a true criterion of plasticity, contrary to the statement of Rohland, who makes the claim that this contraction is the best measure of the property in question.

Cupola Furnace for Melting Iron. R. MOLDENKE. (*Trans. Amer. Inst. Min. Eng.*, 1913, 37.)—In practice the best results are obtained by the use of 300,000 cubic feet of air per hour for a cupola of 54 inches diameter. If the metal is introduced less than eight minutes after the commencement of blowing, the bed is too thin, and should be increased by charging a little more fuel between the metal charges, whilst if it be not introduced until after more than ten minutes the bed is too thick and should be correspondingly reduced. The following conditions should be observed: (1) The proper amount of air required by the capacity of the cupola should be used; (2) the bed coke should be dry and well lighted before charging; (3) the bed should be of the proper height to give "first iron" in from eight to ten minutes; (4) the metal charges should be of equal weight and no larger than will be just covered by the coke required to melt them; (5) the coke charges should be so adjusted to the metal charges that the melting zone remains stationary and at the right point; (6) the blast volume (not pressure) should be constant throughout the heat; (7) the charges should be evenly distributed; (8) only one row of tuyères should be used; (9) the melting rate should be watched and the intermediate coke charges adjusted accordingly; (10) large pieces of metal should be avoided; (11) heavy coke with small percentages of cell space can stand large charges, while light coke with a large percentage of cell space must have very small charges to yield the best results.

Influence of Sulphur on Cast Iron. H. I. COE. (*Proc. Brit. Foundrymen's Assoc.*, 1911–1912, 78.)—A series of test bars was prepared from pure materials and was examined chemically, physically, and metallographically. The results show that: (*a*) With low silicon content a small amount of sulphur causes nearly all the carbon to become combined. With high silicon content the effect of sulphur in this respect is much less marked. (*b*) There appears to be a critical point, which varies with the silicon content, at which the effect of sulphur changes suddenly. (*c*) The addition of sulphur increases tenacity, transverse strength, and hardness. This influence is due partly to its effect on the condition of the carbon, partly to its modifying the dendritic character of the silicious irons. (*d*) Manganese neutralizes the influence of sulphur on the condition of the carbon, and, if in excess, eliminates sulphur by separation as manganese sulphide. Sulphur is most dangerous in irons low in silicon and manganese. These results were obtained in the absence of phosphorus, and probably would be modified in the case of commercial pig iron. Cast iron is desulphurized either by the addition of ferromanganese or by Saniter's process, which consists in mixing burnt lime and calcium chloride with the molten charge, thus producing calcium sulphide. For malleable cast iron, if the Réaumur process is employed, 0.2 to 0.4 per cent. of sulphur may be present, but for " Blackheart " castings 0.05 per cent. is the maximum permissible, since in the Réaumur process the annealing is oxidizing, and the stability of the carbide as regards decomposition into iron and graphite is of little importance, while the production of " Blackheart" castings depends essentially on the decomposition of iron carbide. As sulphur prevents this decomposition, it is therefore harmful.

Chemical Nature of Radioactive Elements. ALEX FLECK. (*Eng.*, xciv, No. 2443, p. 582.)—Mr. Fleck reaches the same conclusion as Marckwald and Keetman, that thorium and uranium X could not be separated. Trying all possible chemical methods, and relying chiefly on fractional precipitation finally, he stated that he had failed to change the concentration of the short-lived radio-elements in thorium. Similarly, he had found radio-actinium and thorium, and thorium B and lead, to represent two pairs of chemically inseparable elements.

Comparison between Rattler Test and Sand-blast Test for Paving Bricks. E. ORTON, JR. (*Trans. Amer. Ceramic Soc.*, xiv, 180.)—On either technical or economic grounds the sand-blast method is found to have no advantage over the rattler process as a method of testing paving bricks for resistance and wear. It measures hardness rather than strength or toughness, and, as a laboratory process, is recommended for exposing the structure of strong bodies, whether natural or artificial.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 16, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 16, 1913.

VICE-PRESIDENT COLEMAN SELLERS *in the Chair.*

Additions to membership, 36.

After the transaction of the usual Institute business a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, Vice-President Sellers and Chairman Hornor presiding jointly.

Vice-President Sellers introduced Dr. G. W. Pierce, Assistant Professor of Physics, Harvard University, who spoke on "The Wireless Telephone."

Dr. Pierce first reviewed the methods of producing high-frequency electric oscillations by the singing-arc, the quenched-spark and the high-frequency generator, illustrating his remarks by lantern slides and by demonstrations of the first and second of these methods.

By means of schematic diagrams, he explained how such oscillations produced the continuous train of magnetic waves necessary for wireless telephony.

He stated that the chief advantage of wireless telephony over telegraphy was that less trouble was experienced from atmospheric and other interferences, since words could be interpreted more easily than signals, even if only a few syllables of such words were audible.

Dr. Pierce stated that wireless telephony had already been successful over a distance of 35 miles.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS—REPORT OF THE DIRECTOR FOR THE SEASON 1912–1913.

(Abstract.)

To all who have the interests of the School at heart, it is a matter of gratification to note that the steady increase in the enrollment, which began with the reorganization of the work in all Departments in 1910, still persists.

In the season 1909–10, 201 students were registered in the School. This had been an average figure for a number of years. The enrollment increased to 232 in the following season. Last year 292 students were reported on the register, and now, during the sessions just completed, 305 students have been in attendance.

Although this latter figure is sufficient to evidence not only the long-continued (the School has just completed its eighty-ninth year) but also the still increasing prosperity of the School, it might here be stated that it represents only the number of individual names on the roll, and therefore takes no special account of the number of students which registered in more than one course. The majority of students attended, as usual, either the Drawing or Naval Architecture classes on Tuesday and Thursday evenings or the Mathematics or Mechanics classes on Mondays and Wednesdays; the register shows, however, that sixteen students attended the School for all four evenings weekly.

Certificates for the satisfactory completion of a two-year course in one of the four departments of Drawing, Mathematics, Mechanics or Naval Architecture are this year awarded to 45 students—an increase of six over last season. As in other years, a large proportion of these certificates goes to students in the Department of Drawing—Mechanical, Architectural or Freehand and Water Color classes—although this season there is a notable increase in the number of graduates in the Department of Mechanics.

The two-year courses offered in both Mathematics and Mechanics embrace several separate subjects, to each of which one term of three months is allotted. This arrangement permits of a number of combinations of subjects to form a complete course for a particular student, but at the same time also lessens the number of possible graduates in these Departments, as so many students follow only partial courses in each.

At the close of the Winter Term seven students in the Department of Drawing were awarded Bartol Scholarships, entitling them to free tuition for the Spring Term, and now seven students are awarded scholarships covering their tuition for the first term of the coming season.

The New York Shipbuilding Company's Prize of a valuable set of drawing instruments is now awarded to the student of greatest merit in the Department of Naval Architecture.

Certificates of Honorable Mention are also now awarded to those students in the respective classes in all Departments who have shown the best attendance and have been most proficient in their work.

The list of graduates for the season 1912–13 is appended.

I desire to express my sincere appreciation of the continued co-operation of my associates in the faculty: Messrs. Wm. E. Bullock, H. C. Towle, Clement Remington, H. P. Tyson, I. P. Pedrick, R. R. Umstead, W. W. Twining, and F. H. Lobb, and of the work of Messrs. Charles Rommel and E. Bark, appointed on the staff this year.

WM. H. THORNE,
Director of the School.

PHILADELPHIA, April 18, 1913.

LIST OF GRADUATES, 1912–13.

Mechanical Drawing.

Frederick J. Benz
Charles F. Carman
Edward C. W. Craven
Otto E. Dannenberg
T. J. Norman Derby
Robert N. Hudson
Herbert Jayes
Charles A. Johnson
James R. Leacock
Thomas Morrissey
George P. Read
William L. Shuster
Peter Siebold
William J. Wear, Jr.
John Weber

Architectural Drawing.

Milton S. Dilworth
Harry Feldman
Albert J. Godfrey
Harry T. Godfrey
Michael Greenberg
William Saidel
Frederick H. Stigale
James T. Strahan
Walter T. Teichman

Freehand Drawing and Water Color.

Sophie Colles
Raymond Murphy

Mathematics.

William J. Hare
Aloysius Hinski
Julius M. Netzer
Otto Roeder
John A. Schneider
August G. Schweizer
T. L. Shannon
Richard M. Warren, Jr.
Louis G. Zelson

Mechanics.

Robert T. Aiman
Clarence E. Bullinger
Eaton Burrows
Karl Fichtner
Stanley B. Furstenau
Frank H. Sauer
Wm. F. Stevenson

Naval Architecture.

H. Y. Bradley
Maury P. Gregg
James G. Morgan

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 2, 1913.*)

Hall of The Franklin Institute,
Philadelphia, April 2, 1913.

Mr. J. A. P. Crisfield *in the Chair.*

The following report was presented for final action:

No. 2529.—The work of Albert Sauveur in connection with the Metallography of Iron and Steel. Cresson Medal. Adopted.

The following reports were presented for first reading:

No. 2526.—C. Francis Jenkins's Motion Picture Apparatus.

No. 2531.—Barr's All-Glass Fruit and Preserve Jar.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A joint meeting of the section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, April 3, 1913, at 8 o'clock.

Dr. George A. Hoadley and Mr. H. A. Hornor presided jointly.

Mr. Hornor presented a communication on "The Electrical Equipment of the Modern Battleship."

The speaker emphasized the lead taken by questions of power distribution in modern ships, with its consequent effect upon the kind of installation advisable. He outlined the uses of electricity for the operation of the various auxiliaries, including pumps, fans, heaters, steering gear, signalling, etc.

Some remarks were also directed to the problem of propulsion by means of electric coupling.

Mr. Hornor's paper was illustrated by lantern slides.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the section was held on Thursday evening, April 10, 1913, in the Hall of the Institute, at 8 o'clock.

Dr. Harry F. Keller in the Chair.

The Chairman called on Dr. Robert H. Bradbury, head of the Department of Science, Southern High and Manual Training School, Philadelphia, member of the Institute, and president of the section, who gave an interesting and instructive lecture on "Colloids and Crystals: The Two Worlds of Matter."

Opening with definitions of the two classes of substances, the speaker continued with illustrations of colloidal solutions and the methods of obtaining and examining them, confining his remarks chiefly to non-reversible colloids. He also discussed the Brownian movement.

At the close of his remarks he prepared hydrosols of gold and silver, and of antimony sulphide, silver bromide, ferric oxide, etc. He also demonstrated the Tyndall effect for examining these sols.

After a brief discussion by members present, a vote of thanks was accorded the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting of the Board of Managers, April 9, 1913.)

NON-RESIDENT LIFE.

MR. J. KEARSLEY M. HARRISON, The Tudor, Beacon and Joy Streets, Boston, Mass.

MR. SAMUEL INSULL, President, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

RESIDENT.

MR. CHAS. M. BALLANTINE, 4810 Germantown Avenue, Germantown, Philadelphia, Pa.

MR. SAMUEL B. BOWEN, North Penn Junction, Philadelphia, Pa.

MR. JOHN F. CONAWAY, National Umbrella Frame Company, Thirtieth and Thompson Streets, Philadelphia, Pa.

MR. CHARLES T. COWPERTHWAIT, 212 South Fourth Street, Philadelphia, Pa.

MR. WM. J. DAVIS, McHatton Foundry Company, Fifteenth Street and Washington Avenue, Philadelphia, Pa.

MR. SAMUEL BALTZ ECKERT, Devon, Chester County, Pa.

MR. N. E. FUNK, 5113 Kingsessing Avenue, Philadelphia, Pa.

MR. W. GRIFFIN GRIBBEL, 1513 Race Street, Philadelphia, Pa.

MR. J. C. HERSHEY, 1014 Market Street, Philadelphia, Pa.

MR. E. E. PENNOCK, 403 Bourse Building, Philadelphia, Pa.

MR. G. A. PIERCE, Wm. Cramp & Sons Ship and Engine Building Company, Philadelphia, Pa.

MR. MARSHALL R. PUGH, 601 Witherspoon Building, Philadelphia, Pa.

MR. PAUL SPENCER, northwest corner Broad and Arch Streets, Philadelphia, Pa.

PROF. W. E. S. TEMPLE, Department of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.

MR. JOHN CASTLE WRIGHT, McHatton Foundry Company, Fifteenth Street and Washington Avenue, Philadelphia, Pa.

NON-RESIDENT.

MR. W. S. ANDREWS, Research Department, General Electric Company, Schenectady, N. Y.

DR. DONALD S. ASHBROOK, 2404 Willard Street, Wilmington, Del.

MR. FRANK L. CONNABLE, 622 Du Pont Building, Wilmington, Del.

MR. THOMAS A. EDISON, Orange, N. J.

MR. JAMES GAYLEY, 71 Broadway, New York City, N. Y.

DR. WM. PAUL GERHARD, Forty-second Street Building, New York City.

MR. W. HERMAN GREUL, 11th Avenue and Twenty-sixth Street, New York City, N. Y.

MR. ALLEN HAZEN, Forty-second Street Building, New York City, N. Y.

DR. EDWARD P. HYDE, 4503 Hough Avenue, N. E., Cleveland, Ohio.

DR. JOHN PRICE JACKSON, School of Engineering, The Pennsylvania State College, State College, Pa.
MR. WALDEMAR KAEMPFFERT, *Scientific American,* 361 Broadway, New York City, N. Y.
DR. JOHN F. KELLY, Pittsfield, Mass.
MR. H. WARD LEONARD, Lawrence Park, Bronxville, N. Y.
MR. OTTO LUYTIES, 546 Fifth Avenue, New York City, N. Y.
DR. ALFRED NOBLE, 7 East Forty-second Street, New York City, N. Y.
MR. MATHIAS PFATISCHER, 314 East Third Avenue, Roselle, N. J.
MR. FRANK J. SPRAGUE, 165 Broadway, New York City, N. Y.
PROF. CARL C. THOMAS, College of Mechanics and Engineering, The University of Wisconsin, Madison, Wis.
DR. MAXIMILIAN TOCH, 320 Fifth Avenue, New York City, N. Y.

Changes of Address.

MR. WALTER ATLEE, 410 Exchange Building, Los Angeles, Cal.
MR. EDWIN M. CHANCE, 61 South Pennsylvania Avenue, Wilkes-Barre, Pa.
MR. CHARLES DAY, 611 Chestnut Street, Philadelphia, Pa.
MR. EDWARD V. D'INVILLIERS, 518 Walnut Street, Philadelphia, Pa.
MR. W. R. HUTTINGER, 19 West Ridgewood Avenue, Ridgewood, N. J.
CAPT. A. F. LUCAS, 429 West 117th Street, New York City.
MR. F. H. SHELTON, 1714 Delancey Street, Philadelphia, Pa.
MR. JOHN E. NETHERY, 3333 North Broad Street, Philadelphia, Pa.
MR. CHAS. W. MCMEEKIN, Nevada City, Cal.

NECROLOGY.

James McCrea, eighth president of the Pennsylvania Railroad Company, was born in Philadelphia in 1848. He entered the service of the company at the age of seventeen and rose from the ranks. By 1882 he had attained the position of general manager of the Pennsylvania lines west of Pittsburgh. He became first vice-president a few years later, and, in 1907, president of the Pennsylvania system, succeeding Mr. A. J. Cassatt, whose great work he took up and successfully completed. His death in March of this year occurred shortly after his resignation, which latter was brought about by a personal desire to relinquish his arduous duties after nearly a half century of service.

Mr. McCrea was a member of the Institute since 1907.

William H. Merrick, retired financier and a patron of art, died on April 15th, at his residence in Germantown, Philadelphia, at the age of 82 years. Mr. Merrick was educated in the public schools of Philadelphia and at the University of Pennsylvania. He was for some years Director of the Philadelphia Savings Fund Society. He was one of the founders of the

Academy of the Fine Arts and School of Industrial Arts and the Zoölogical Society. His membership in local organizations included the American Philosophical Society and The Franklin Institute, with which latter he became connected in 1904.

Mr. Merrick was the son of Samuel V. Merrick, first president of the Pennsylvania Railroad and president of The Franklin Institute from 1842 to 1854.

Friedrich W. C. Schniewind was born at Bochum, in Westphalia, in 1861. He studied chemistry at Berlin, Munich, and Heidelberg, receiving the degree of Ph.D. from the University of Heidelberg. After some experience as a blast-furnace chemist, he came to this country in 1890 and conducted analytical laboratories at Cleveland, Ohio, and Crystal Falls, Mich. Four years later he became connected with the Otto Coke and Chemical Company, organized to introduce by-product coke ovens into this country. The United Coke and Gas Company succeeded the original company, and Dr. Schniewind acted as consulting engineer, later becoming manager and vice-president.

He was the author of numerous papers on coal carbonization, coke production, ammonia, benzol enrichment, and other subjects in industrial chemistry.

Dr. Schniewind was elected to membership of The Franklin Institute in 1905.

Mr. Samuel H. Cramp, Philadelphia, Pa.

LIBRARY NOTES.

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GRAY, A.—Electrical Machine Design. 1913.

HESS, H. D.—Machine Design. 1912.

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Syracuse University, Bulletin, University number, March, 1913. Syracuse, N. Y., 1913. (From the University.)

United States Coast and Geodetic Survey, Report of the Superintendent for 1912. Washington, D. C., 1913. (From the Superintendent.)

University of Toronto, Calendar 1913–1914. Toronto, Can., no date. (From the University.)

Waltham Water Department, 40th Annual Report. Waltham, Mass., 1913. (From the Department.)

Washington University, 56th Annual Catalogue. St. Louis, 1912. (From the University.)

Wilmington Board of Park Commissioners, Report for 1912. Wilmington, 1912. (From the Commissioners.)

BOOK NOTICES.

THE TECHNICAL ANALYSIS OF BRASS AND THE NON-FERROUS METALS. By William Benham Price, Chief Chemist, Scovill Manufacturing Company, and Richard K. Meade, Director of Meade Testing Laboratories, Allentown, Pa. 267 pages; illustrated; 12mo. Edition 1. New York, John Wiley & Sons, 1911. Price, $2.

After critical examination of this "handy volume" from title page to index the writer does not hesitate to say that he finds it crammed with valuable information in concentrated form,—*i.e.*, boiled down to smallest bulk,—and nothing appears to have been lost in the operation.

It is crystallized knowledge and experience in a special field which will be found especially useful to the busy man who does not have time or opportunity, amidst other occupations, to keep himself posted on all the modern methods of rapid analyses of brass and other non-ferrous alloys.

The authors have confined themselves rigidly to the main theme, covering practically all known methods of analysis, and do not refer to the specific gravity or microstructure of alloys. While these are very important adjuncts, they are not strictly germane to the work in hand, and would, if included, unduly enlarge the volume.

Few persons realize the enormous expansion of consumption of non-ferrous metals in recent years. Some idea of the economic value of bearing metals alone may be gained from a brief statement on the first page of the Introduction, which is as follows: "In view of the increase in the amount of machinery and rolling stock it is safe to say that the value of the bearing metal now in use is considerably over fifty million dollars." Presumably the authors are referring to this country only.

A feature which has impressed the reviewer favorably is the proper balance which appears to have been observed in respect to the relative importance of various methods of analysis of the metals and alloys. Thus, the electrolytic method is given prominence, wherever it is available, as being the simplest and most rapid, and where the electrolytic process is not suitable a brief note (as in the case of magnesium) is given, viz., "None at present known."

In the case of aluminum it is shown that this metal may be electrolytically separated as aluminum hydroxide, filtered off, ignited, and weighed as Al_2O_3, but it is said "this method is seldom used in practical work."

Notwithstanding statements that have been made from time to time in foreign technical journals that processes have been devised whereby aluminum may be "electrolytically deposited in metallic form" on other metals, this is still a mere *ignis fatuus.* The most glaring fraud ever perpetrated of this nature was in the claim made, years ago, that the cast-iron plates forming the metal covering of the great tower of the City Hall in Philadelphia were heavily coated with aluminum electrolytically deposited, and that they would consequently retain, for all time, the original neutral gray color, matching the stone on which the tower rests. Many thousands of dollars were paid by the city for this work, and it will be necessary, sooner or later, to paint the metal work in order to prevent further rusting from exposure of the iron to the elements.

A pleasing feature of this book is the evident care that has been taken to give due credit, in footnotes, to the authors of various methods, or modifications of methods, therein described.

The book is divided into three parts, covering 260 pages in all: Part I—*Introduction;* Chapter I, Engineering Alloys; Chapter II, Apparatus for Electro-chemical Analyses. Part II—*Determination of the Metals.* Aluminum, Antimony, Arsenic, Bismuth, Cadmium, Copper, Iron, Lead, Magnesium, Manganese, Nickel and Cobalt, Phosphorus, Silica, Sulphur, Tin, Zinc. Part III—*Applied Examples of Alloy Analysis.* Aluminum Alloy, Antimony and Arsenic Alloy, Antimony, Arsenic and Tin Alloy, Antimony and Tin Alloy. Antimony and Lead Alloy, Babbitt Metal, Fusible Metals, Solders, etc., Brass, Bronze, Phosphor Bronze, Manganese-Phosphor-Bronze, German Silver, Watch Nickel, and Nickel Alloys, Spelter, Refined Copper Analysis, Exact Electrolytic Assay of Refined Copper, Determination of Arsenic and Antimony in Copper. Table of factors for use in alloy analysis.

The illustrations are drawn in outline and are reduced to the simplest forms; the only criticism to be offered is that there might be more of them with advantage to the text.

Finally, there is an Index covering several pages.

A. E. Outerbridge, Jr.

Methods of Measuring Electrical Resistance. Edwin F. Northrup, Ph.D. McGraw-Hill Book Company, 1912. Price, $4. 8vo, 390 pages, numerous illustrations and diagrams.

The modern tendency toward specialization, and the wisdom of specializing are both well illustrated by the publication of this normal-sized book, which is devoted exclusively to the measurement of only one of the numerous electrical quantities. Not only did there exist enough material on the measurement of electrical resistance to fill a book, but the author makes no claim that even this compilation is a complete collection of all the methods, although it is no doubt the most complete one published, and apparently the first book ever published which is limited to resistance measurements alone.

The author has hereby set a good example, which could well be followed by others, as the books which promise to be most useful to the workers in theoretical and applied sciences are those in which are compiled the scattered products of the brains of many, as distinguished from a book which originated entirely in one brain. A book which can be depended upon to contain a complete collection of all existing knowledge on any specific subject is one which no one dealing with that subject, even only occasionally, can afford to do without. It is hoped that the present author's good example will be followed by similar collections of methods of measuring the other electrical quantities.

There are probably few who would be better suited to prepare such a book than this author, who combines the ability to deal with the higher mathematics involved with many years of experience in laboratory testing and in the designing and making of instruments to carry out methods of making electrical measurements. Some of the methods are claimed to be new, and others are the author's modifications of methods devised by others.

The general plan of the book is that of a treatise rather than that of a reference book, the mathematical evolutions of final formulas being given, in many cases, in considerable details, unnecessarily detailed for the user of the methods, but useful to the student, the teacher, and the mathematical physicist. It is, however, also available as a reference book, although in some cases one may have to search under various headings and chapters to find all the available methods for any particular case.

The grouping and classifications of the methods might be open to criticism and possible improvement, as it sometimes brings the same subject under widely differing groups, the method of measuring the resistance of electrolytes, for instance, falling partly in Chapter II and partly in Chapter XI, due to what seems to the reviewer to be a somewhat unfortunate classification or grouping. But, owing to the complicated nature of any system of classification of such methods, it is hardly fair to the author to find fault with his method unless one can offer a better one.

One of the features which enhances the value of the book is that in many cases the author has himself applied and studied the particular method described and is therefore able to supplement the description with actual experience.

Supplementary chapters are devoted to discussion of measurements in general, including the estimation of errors, to instruments and their choice for specific measurements, and in an appendix are given interesting tables and data of use in such measurements.

The method of numbering the sections with the chapter number as the hundreds, and the numbering of the figures with the corresponding section numbers, greatly facilitate references and can be highly recommended to other authors of similar books as being useful and practical; it seems to be new in this book. From a book-maker's standpoint the book is all that can be desired in clearness of type and illustrations, most of which latter are original and are made by the so-called "wax" process, with very clear and distinct lettering.

The book shows unusual care and conscientiousness in its editing, which is quite in accordance with the usual careful, earnest, and conscientious work of that author. It is not likely that it will be found to contain the errors of carelessness and in typography which are, alas! too common in less carefully prepared books, and which tend to develop the thought that the same lack of attention and care was devoted to the matter itself.

The reviewer feels no hesitancy in recommending this book very highly to the teacher, the student, the worker in testing laboratories, and the practical electrical engineer, and he expresses the hope that it will be followed by further volumes giving compilations of the methods of measuring the other electrical quantities.

CARL HERING.

Die elektrolytische Alkalichloridzerlegung mit starren Metallkathoden. By Dr. Jean Billiter. Published by Wilhelm Knapp, of Halle. 284 pages, 24.5 x 17 cm. Price, 16.50 marks.

This is part I of a comprehensive treatment of the subject of the electrolysis of the chlorides of potassium and sodium with solid metal cathodes. It forms No. 41 of Knapp's *Monographien über angewandte Elektrochemie*. Processes in which cathodes of mercury or of melted lead are employed are excluded, because they have already been treated in Lucion's monograph, which forms No. 23 of the same series.

With the exception of a brief but excellent introduction, the present volume is devoted to the patent literature of the subject. Four hundred and fifty German, English, and American patents are concisely and intelligibly discussed. Numerous diagrams add to the clearness of the text. The author has himself made important contributions to the subject, and some of the most successful processes described are his own.

Part II, which is ready for publication, will contain complete descriptions of the plants in which those processes which have found industrial application are carried out. The fact that a work which will probably approach 600 pages is necessary adequately to treat only one phase of the subject of the electrolysis of the alkali chlorides is impressive evidence of the activity of invention in the field. The book is an excellent one, which can be recommended without reserve to those interested in the subject. Since about 70,000 horsepower are devoted to sodium chloride electrolysis in the United States, it will probably be welcome to many American chemists. There is a list of the patents in order of number and a good alphabetical index.

Robert H. Bradbury.

An Introduction to the Chemistry and Physics of Colloids. By E. Hatschek. Published by P. Blakiston, Philadelphia. 87 pages, 18.5 x 12 cm. Price, $1.

An excellent and timely little book. Although it offers a surprising amount of information in small space, it is readable and interesting. The author is fully familiar with the present condition of his subject, and the reviewer has noted no misstatements. The book is not overloaded with terminology, and the essential things that everyone wants to know are presented clearly and well.

Robert H. Bradbury.

Allen's Commercial Organic Analysis, vol. vii, 4th edition, edited by W. A. Davis and S. S. Sadtler, published by P. Blakiston. 563 pages, 23.5 x 14.5 cm. Price, $5.

The previous volumes of this indispensable treatise have been noticed. The present volume is devoted to Vegetable Alkaloids (Barger), Glucosides (Armstrong), Bitter Principles (Jones), Animal Bases (Taylor), Ptomaines (Barger), Animal Acids (Mandel), Lactic Acid (Davis), Cyanogen and its Derivatives (Philipp). Although the familiar order of the third edition has been retained as far as possible, the whole book has been rewritten and brought abreast of the present state of organic analysis. It may be well to call attention to the fact that most of the more important vegetable alkaloids have already been handled under various headings in vol. vi.

ROBERT H. BRADBURY.

PUBLICATIONS RECEIVED.

An Introduction to the Physics and Chemistry of Colloids, by Emil Hatschek. Reprinted from *The Chemical World.* Text-books of Chemical Research and Engineering, 94 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1913. Price, $1.

Allen's Commercial Organic Analysis, a treatise on the properties, modes of assaying, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicine, etc. Vol. 7. Vegetable alkaloids, glucosides, non-glucosidal bitter principles, animal bases, animal acids, lactic acid, cyanogen and its derivatives, by the editors and the following contributors: Frankland Armstrong, G. C. Jones, A. E. Taylor, G. Barger, J. A. Mandel, Herbert Philipp. Fourth edition, entirely rewritten. Edited by W. B. Davis, B.Sc., A.C.G.I., and Samuel S. Sadtler, S.B. 563 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Co., 1913. Price, $5.

Mechanical Drawing, a treatise on technical drawing as expressed through the medium of the graphic language, by Otho M. Graves, Assistant Professor of Graphics, Lafayette College. 138 pages, illustrations, 8vo. Easton, Pa., The Chemical Publishing Company, 1912. Price, $2.

U. S. Department of Agriculture, Forest Service, Henry S. Graves, Forester: Geographic Distribution of North American Trees. Part 1—Pines, by George B. Sudworth, Dendrologist. 36 maps, folio. Washington, U. S. Geological Survey, 1913.

Paving Brick: The Necessity of Uniform Quality. Tests for High-grade Paving Bricks, by J. W. Howard, C.E., E.M. 15 pages, illustrations, 8vo. New York, author, 1913.

North Carolina Geological and Economic Survey, Joseph Hyde Pratt, State Geologist: Economic Series No. 32, Public Roads are Public Necessities, by Joseph Hyde Pratt, State Geologist. 62 pages, 8vo. Raleigh, State Printers, 1913.

American Telephone and Telegraph Company, Annual Report of the Directors to the Stockholders for the year ending December 31, 1912. 47 pages, 8vo. New York, 1913.

U. S. Department of Agriculture, Forest Service: Review of Forest Service Investigations, vol. 1. 68 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1913.

U. S. Department of Agriculture, Office of Public Roads: Bulletin No. 47, Descriptive Catalogue of the Road Models of the Office of Public Roads, prepared in the Office of Public Roads. 29 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1913.

U. S. Bureau of Mines: Bulletin 52, Ignition of Mine Gases by the Filaments of Incandescent Lamps, by H. H. Clark and L. C. Ilsley. 31 pages, illustrations, plates, 8vo. Bulletin 63, Sampling Coal Deliveries and Types of Government Specifications for the Purchase of Coal, by George S. Pope. 68 pages, illustrations, plates, 8vo. Technical Paper 31, Apparatus for the Exact Analysis of Flue Gas, by George A. Burrell and Frank M. Seibert. 12 pages, illustrations, 8vo. Washington, Government Printing Office, 1912, 1913.

Canada Department of Mines, Mines Branch: Bulletin No. 8, Investigation of the Peat Bogs and Industry of Canada, 1910–11, by A. Anrep. 61 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1912.

Bulletin of the Efficiency Society, Inc.: Volume 2, January, February, March, 1913. 47 pages, illustrations, quarto. New York, Society, 1913.

Prime Movers. S. Z. DE FERRANTI. (*The James Watt Lecture, Greenock,* 1913.)—Mr. Ferranti states that he has devised a turbine which is quite free from mechanical troubles at the highest temperature, and with great and rapid variations of temperature. The blading is of mild steel, electrically welded throughout, and with a thin coating of pure sheet nickel electrically welded on to the surface. The steam is worked as a gas at high temperature throughout the turbine; it is superheated initially and after the first expansion, then re-superheated before it does work in the second stage of the turbine, and exhausted in a superheated condition through a regenerator to the condenser. A 5000-horsepower turbine of this kind, which has been running for some time, when tested at a load of two-thirds full power on 7 pounds of steam, gave results corresponding to a consumption of 0.625 pound of oil per shaft-horsepower, with the steam supplied by an oil-fired boiler superheater system of 85 per cent. efficiency. The results now obtained indicate that when run at full load under favorable conditions this turbine will take less than 6 pounds of steam per shaft-horsepower and that the system will have a thermal efficiency of over 24 per cent., corresponding to an oil consumption of about 0.55 pound of oil per shaft-horsepower.

Solubility of Metals and Alloys. (*Mon. Sci.*, xxv, 837.)—Certain metals and alloys prepared in the electric furnace, which sometimes resist the most energetic chemical action, are readily attacked and completely dissolved when powdered and heated with an excess of phosphoric acid above 1.75 in density. This applies to metallic silicon, zirconium, tungsten, ferro titanium, vanadium, silico-manganese, titanium nitride, the alloy of ferrosilicon with 23 per cent. aluminum, boron-nickel, and carborundum. In all these reactions the carbon contained in the alloys remains, wholly or partially, in a flocculent condition in the syrupy liquid.

CURRENT TOPICS

The Chemical Constitution of the Kaolinite Molecule. J. W. Mellor and A. D. Holcroft. (*Trans. Eng. Ceram. Soc.*, xi, 169.)—The heating curve and dehydration curve of well-defined crystals of kaolinite from the Glamorganshire coal field were determined. The thermal phenomena exhibited in the heating curve were similar to those of a china clay, a slight terrace in the curve being due to decrepitation and projection of the material from the crucible. The dehydration test confirmed the result previously obtained, that there is no definite temperature of dehydration. The total loss on ignition was 15.94 per cent., but the content of organic matter was large, and some other mineral, possibly halloysite or montmorillonite, was present to the extent of 10 to 15 per cent.

The Degree of Porosity of Paper. W. Colditz. (*Wochenbl. Papierfabr.*, xliv, 376.)—Printing papers require a harder or softer sizing according to the nature of the printing to be done and the consistence of the ink. It is not sufficiently recognized that the resistance or absorbency of paper toward oily printing inks has no direct connection with the hardness of sizing as usually measured in relation to aqueous writing inks. The resistance to oily inks depends on the closeness of texture and relative porosity of the paper. In default of a direct method of measuring the rate of penetration of oil varnishes through printing papers, the author adopts a method dependent on the fact that the porosity is expressed by the ratio of the apparent specific gravity of the paper to its real specific gravity. The apparent specific gravity is calculated by ascertaining the weight of a measured volume of the paper, whilst the real specific gravity of the solid constituents of the paper is calculated by ascertaining the amount of oil displaced by a given weight of the paper. For this purpose olive oil is employed, and it is essential to steep the paper in the oil for at least half a day to ensure the complete displacement of the air before the weighing is made. The procedure is the usual method of determining the specific gravity of solid bodies; a sinker large enough to contain the sample of paper is used, and its displacement of both oil and water has been previously determined.

Australian Radium. Anon. (*Sci. Amer.*, cvii, 26, 547.)—The *London Times* says the first sample of radium bromide produced outside of Europe has lately been manufactured in Sydney from Australian ores, and has a certified purity of 98.4 per cent. The plant is capable of producing 40 milligrammes weekly.

Production of Lead, Zinc, and Cadmium in 1911. ANON. (*Chem. Trade J.,* Dec. 14, 1912.)—*Lead.*—The annexed table shows the world's production of lead, in short tons, during the years 1909–11, inclusive:

Country.	1909.	1910.	1911.
Australia	85,098	108,907	109,789
Austria-Hungary	15,432	19,290	21,605
Belgium	44,423	44,864	33,951
Canada	22,928	16,535	11,795
France	29,652	22,266	25,353
Germany	185,076	176,258	177,801
Great Britain	31,085	32,628	29,872
Greece	16,865	18,519	15,763
Italy	24,361	15,983	18,408
Japan	3,748	3,858	3,858
Mexico	130,071	133,048	132,276
Russia	882	1,323	1,102
Spain	202,823	211,531	189,155
Sweden	220	441	2,866
Turkey in Asia	13,338	13,999	13,668
Other Countries	6,393	17,306	20,944
United States (domestic)	354,188	372,227	392,842
Total	1,166,583	1,208,983	1,201,048

Zinc.—The world's production of spelter in 1911 was again the largest in history, exceeding that of the record output of 1910 by 85,549 tons, or 9.6 per cent. The greatest increase was contributed by Germany, which exceeded its 1910 production by 24,962 tons. Belgium made a gain of 24,817 tons, and the United States 17,342 tons. The following totals, apportioned according to the country where smelted, and not according to the source of the ore, show the world's production, in short tons, during the years 1909–11, inclusive:

Country.	1909.	1910.	1911.
Australia		560	1,904
Austria and Italy	13,931	14,666	18,602
Belgium	184,194	190,233	215,050
France and Spain	61,859	65,191	70,791
Germany	242,594	251,046	276,008
Great Britain	65,422	69,531	73,803
Holland	21,548	23,121	25,059
Poland	8,758	9,514	10,952
United States	255,760	269,184	286,526
Totals	854,066	893,046	978,695

Cadmium.—The chief output of cadmium comes from the zinc-producing regions of Silesia, Germany, where it is recovered as a by-product in the distillation of zinc. Recently, in the United Kingdom, a little cadmium has been recovered in the purification of zinc sulphate in the manufacture of lithopone. The German production of cadmium during 1911 totalled 93,961 pounds, valued at $53,375, against 90,516 pounds, valued at $39,315, in 1910.

Mantles for Incandescent Gas Lighting. C. R. BÖHM. (*J. Gas Lighting,* cxxi, 33, 100, 181.)—*Knitting.*—The different kinds of web produced on the round knitting machine have the drawback of being less pliable than the ordinary web. Cotton mantles appreciably decrease in brilliancy after use, those of ramie are very constant, but the artificial silk mantles, now coming into use, combine the high and well-maintained illuminating power of ramie fibre with a great elasticity of the ash skeleton. Cuprammonium cellulose, chardonnet, and viscose silks are all used for the manufacture of mantles.

Washing.—Both cotton and ramie mantles require washing before impregnating, to remove the fat and mineral matter; this was done formerly by using a 3 to 5 per cent. solution of soda, followed by a 1 to 3 per cent. solution of hydrochloric acid. Recently, however, the process has been simplified; the mantles are soaked over night in a 2 per cent. solution of nitric acid and the next morning they are centrifuged, treated with a weak solution of ammonia, and then washed, first with condensed and afterward with pure distilled water.

Drying.—The mantles are dried in a current of hot air, and the imperfect ones sorted out. From this point scrupulous cleanliness in handling the mantles is imperative.

Impregnation.—The mantles are impregnated by being soaked in a 25 to 33 per cent. aqueous solution of thorium and cerium nitrates in the proportion of 99:1, to which very small amounts of beryllium and magnesium nitrates are added to harden and strengthen the ash skeleton. After soaking in this liquid for a time —from one to two minutes in the case of cotton or ramie mantles, and five hours for artificial silk mantles—they are passed through a wringing machine. The quantity of salts left in the mantles can be varied by adjusting the rollers of the wringer. The mantles are next dried at a temperature not exceeding 30° C.; the cotton and ramie mantles, cut in short lengths before impregnation, are stretched over glass cylinders, and the artificial silk mantles, impregnated in lengths, are run over wooden rollers. The upright mantles are then fitted with a tulle head sewn on, or with a patent head, and this is fixed by treatment with a 50 per cent. aqueous solution of aluminum and magnesium nitrates. Then the asbestos loop by which the mantles are suspended is sewn on. The inverted mantles are drawn together with impregnated cotton, to form the "spider," and are then fastened on to the supporting ring.

Burning Off.—If a trade-mark is desired on the mantle, this is stamped on with a solution of didymium nitrate, dissolved in a mixture of alcohol, distilled water, and glycerine, to which a little methyl Blue has been added. Then the mantle is shaped on a wooden shaper and is burned off. This is done with a Bunsen flame, beginning at the top of the mantle, and the mantle is hardened by increasing the pressure of the gas for a period of 1½ to 15 minutes.

The mantles now consist of a skeleton of ash and are ready for use, but they will not bear transportation. Therefore they are dipped in a collodionizing solution, consisting of 100 parts of 4 per cent. collodion solution, 40 parts ether, 6.5 parts camphor, and 3.5 parts castor oil. After rapid drying at a temperature of from 50° to 60° C., the mantles are trimmed to the proper length, sorted out into different qualities, and the imperfect ones rejected. Then follows a list of various defects to which mantles are liable, and the causes to which these defects may be attributed.

Vanadium-Aluminum Alloys. N. CZAKO. (*Comptes Rendus,* clvi, 140.)—M. Czako obtained alloys with 30 to 80 per cent. of vanadium by reducing vanadic acid with aluminum in crucibles lined with magnesia. Alloys with a lower percentage of vanadium have been obtained by melting these products with aluminum in suitable proportions. Micrographic study of the alloys suggests the existence of the compounds Al_3V, AlV, and AlV_2. The first two have been isolated from the alloys of which they formed the chief part by the regulated action of acids. It is as yet uncertain whether AlV_2 is a definite compound. With up to 10 per cent. of vanadium the alloys are still malleable. From 20 to 25 per cent. they may be pulverized in a mortar. Up to 53 per cent. they contain numerous cavities, which make it difficult to obtain a polished surface. The hardness increases with the percentage of vanadium up to 53 per cent., when it is between 6 and 7. With from 60 to 80 per cent. of vanadium the alloys are less hard and free from cavities.

Solubility of the Active Deposit of Thorium. C. F. HOGLEY. (*Phil. Mag.,* xxv, 330.)—The active deposit from thorium hydroxide contained in a metal dish was collected on a piece of platinum foil suspended over the dish and connected with the negative pole of a battery. The foil was then submitted to the action of the various solvents examined. Aqueous solutions of salts, hydroxides, and acids dissolved both thorium B and thorium C, but always a relatively larger amount of the former. The solubility in boiling water is small and slow; that in a boiling solution of potassium iodide is more than twice as rapid. Dilute acids, even cold, dissolve the deposit still more rapidly. Organic solvents dissolve at about the same rate as water, but chiefly thorium C. Thorium B is quite insoluble in chloroform and methylene iodide.

Ether Admitted Duty-free to Holland. ANON. (*Board of Trade J.,* Feb. 13, 1913.)—A Dutch royal decree, dated January 15, 1913, provides for the duty-free admission to the Netherlands, under certain conditions, of sulphuric ether required in factories or workshops as an aid for the preparation of iodoform gauze and iodoform cotton wool.

Micrographical Studies on Copper, Iron, and Steel. ANON. (*Atelier des Essais de métaux de la Cie. des Chemins de Fer. P. L. M.*)—(1) *Rapid estimation of arsenic in red copper.*—By etching the polished metal with pure nitric acid at 22° C. for five or six seconds, black spots are developed, the number of which, it is stated, bears a direct relation to the arsenic content of the metal. By comparing the metal under examination with a prepared scale of standard specimens of known arsenic content the percentage of arsenic present may be estimated to within about 0.06 per cent., as it is claimed. (2) *Cutting steel with the oxyacetylene blowpipe.*—When sheet or forged steel is cut by means of the oxyacetylene blowpipe, a zone of higher carburization is produced along the cut edges of the metal. Since in the cases examined the width of the zone was about 5 mm., it is considered that the edges of all plates, etc., so cut should be removed for a depth of 10 mm. to ensure the absence of affected metal from the finished articles. (3) *Effect of cold work on steel.*—It is found that the effect of cold work due to threading screws of large diameters is that the metal becomes much harder in the neighborhood of the thread than in the middle, to a depth of 3 or 4 mm.; the ferrite present in this zone was crushed and disseminated in fine needles. It is recommended that, after threading, all coupling-screws should be re-annealed at about 700° C. (4) *Adulteration of wrought iron* by the insertion of rolled cast steel in the "fagots" may be readily detected micrographically, the pearlitic zones being better defined and more marked when puddle steel has been introduced.

Kinetic Properties of a Molecule in a Substance. R. D. KLEEMAN. (*Phil. Mag.*, xxiv, 107.)—This is a further discussion of the question as to whether the kinetic energy of a molecule in a liquid is the same as that in a gas at the same temperature; the discussion is based on the hypotheses mentioned in a previous paper. It is concluded that the average velocity of a molecule in a liquid may be several times that corresponding to its temperature. A general formula is deduced for the coefficient of viscosity for matter of any density. General formulæ are also given for the coefficients of heat and of diffusion.

Australian Hard Wood. ANON. (*Amer. Mach.*, xxxviii, 3, 110.)—One of the most remarkable of the many valuable Australian hard woods is yate. Apparently this is the strongest timber known. Its average tensile strength is 24,000 pounds to the square inch, equalling that of good cast iron. Many specimens are much stronger, and one was tested up to 17½ tons per square inch, which is equal to the tensile strength of wrought iron. The tree grows to a maximum height of 100 feet, and sometimes attains a diameter of two and one-half or even three feet.

Mineral Oil Exports from the United States in 1912. ANON. (*Oil, Paint, and Drug Rep.*, Feb. 3, 1913.)—The exports of mineral oils from the principal customs districts of the United States in 1911 and 1912, which represent about 92 per cent. of the shipments from all ports, were as follows:

	1911		1912	
	GALLONS	AMOUNT	GALLONS	AMOUNT
Crude.	184,984,498	$5,791,211	172,822,223	$6,373,771
Illuminating.	1,108,333,605	60,857,290	1,023,681,414	61,918,491
Naphthas.	131,286,657	10,988,213	175,089,771	19,365,132
Lubricating and paraffin..	181,259,004	22,977,857	213,559,784	27,860,862
Residuum, gas and fuel oil.	136,366,250	3,771,749	259,376,853	6,357,136

Filaments for Incandescence Electric Lamps. E. MORSAINT. (*French Pats. 446,140 and 446,310*, July, 1912.)—(1) Carborundum crystals are ground very fine, treated with *aqua regia* to remove metallic impurities, washed, dried, and formed into a paste with a carbonaceous binding material. The paste is formed into filaments, which are sprinkled with carbon to prevent adhesion, dried and heated in a closed chamber for four to five hours at a temperature of 600° C., after which the temperature is slowly raised to 1500° or 1600° C. The carbon is then burned off by heating the filaments to a red heat in dry air, and they are finally heated to 2000° C. in an electric furnace. It is claimed these filaments are not injured by excessive voltage. (2) Carborundum filaments prepared as above, but while still in the porous condition, are soaked in a liquid, such as collodion, containing finely-divided silicon in suspension. The liquid must be such that no trace of free carbon is left in the filament after it has been exposed to a red heat in a very slightly oxidizing atmosphere. After removing the free carbon the filaments are heated for two or three hours to 2000° C. in an electric furnace, whereby a filament composed of a crystalline aggregate of pure carborundum and silicon is obtained.

Suction between Vessels. A. H. GIBSON and J. H. THOMPSON. (*Engineer*, cxiv, 313.)—The following experiments were conducted on the Firth of Tay to obtain some information as to the magnitude and range of action of the forces involved in the case of "suction" or interaction between passing vessels. Two screw-propellers were used—the *Princess Louise*, 88.5 feet long, 13 feet beam, 5.66 feet mean draught, about 96 tons displacement, and a motor-launch 29.33 feet long and 6.75 feet beam. Two sets of experiments were carried out. In the first the vessels were manœuvred until on sensibly parallel courses, heading for the same distant object, their lateral distances apart and speeds being varied in different trials. Their courses having been satisfactorily fixed with the helm of the motor boat amidships, this helm was lashed, the helm of the *Princess Louise* being later manipulated so as to keep her on her original course. The second series of experiments was carried out with the view of measuring the helm angle required to maintain the course of the smaller vessel when in the vicinity of the larger one. In these experiments the relative positions of the two boats were obtained as in the first set, the helm being adjusted as required to keep the head of the vessel on its original course. Full details are given and diagrams showing the relative paths and positions of the two vessels under varying speeds and in different relative positions. The general conclusions deduced are: The greater the difference between the speeds of the vessels, the smaller is the risk of collision, since such a difference reduces the time during which the mutual forces are operative, such an effect being much more marked when the smaller vessel is the faster. But if the larger vessel is the faster, and particularly if her speed is accelerated while passing the smaller, the attractive forces are increased to an extent which partially, and in some cases entirely, counterbalances the effect of the reduction of the time during which the vessels are in dangerous proximity. Hence any attempt of the larger vessel to draw ahead of the smaller greatly increases the risk of collision. The results of the trials show that, under favorable circumstances, interaction is a very real danger to navigation, even in deep and open water. With vessels of the relative sizes adopted for the experiments, if the possibility of interaction is realized from the very first, and if all initial swerve is prevented by an early application of the helm, there would appear to be little danger even at lateral distances so small as one-half the length of the smaller vessel; but if this possibility be not realized, and such a swerve has once started, a much greater helm angle is necessary to control the vessel, and, failing *immediate control*, collision occurs within comparatively few seconds even from astonishingly great distances. The importance of this fact is more readily grasped when it is realized that with a vessel, say, 300 feet in length, passing a vessel, say, 900 feet in length, the forces of interaction have to be reckoned with even when the vessels are 1000 feet apart laterally, a distance which would ordinarily be considered to be giving the larger vessel a very wide and safe berth.

Molybdenum in the Liege Coal-pits. A. JORISSEN. (*Bull. Soc. Chim. Belge,* xxvii, 21.)—Molybdenum is detected in the soot and ashes from Liège coal; in some cases molybdenum compounds may be extracted from the soot or ash by water. The red-colored heaps of débris resulting from the slow combustion of the coal contain appreciable quantities of molybdenum, which appears to be distributed throughout the coal fields. Coal from the Charleroi mines also contains molybdenum.

New Sources of Wood Oil. (*U. S. Cons. Report, Ch. of Comm. J.*, Feb., 1913.)—Wood oil is produced from the nuts of the "tungshu" tree (*Aleurites fordii*) of China, and practically the entire supply comes from that country. Its normal price is 2s. 6d. (60 cents) per gallon, and in the fiscal year ending June 30, 1911, the United States imported 5,000,000 gallons. The wood oil tree will grow along the Pacific coast, south of Sacramento, and in the Gulf States. There are no groves of these trees in the United States from which data as to the commercial production can be obtained. Another source of supply is the Kukui nut or candlenut, which grows in Hawaii and the Philippines. If the nuts can be gathered and the oil extracted profitably, this oil should compete with Chinese wood oil.

Blast-Roasting of Sulphide Ores. J. H. LEVINGS. (*Inst. Min. and Met.*, Jan. 16, 1913.)—Since 1900 satisfactory results were obtained from the Huntington-Heberlein process at Zeehan, Tasmania, where it was first used outside of Europe. The ores contained lead and zinc. It was found that coarser limestone up to 12 mm. size could be used without harm, and further experiments with the Carmichael-Bradford process showed that iron and manganese oxides could be substituted for limestone with equally good results. Roasting was done by lighting a fire in the pot and then filling with the mixture of ironstone and ore. It is advantageous to give a preliminary roasting in mechanical furnaces before pot-roasting with ores containing much over 10 per cent. of sulphur. The constituents of the ore mixture should be in the approximately correct proportions to form a slag. The shape of the pot exerts a marked influence on the process. At another plant attempts to roast an ore consisting mainly of iron pyrites in silicious gangue, which contained 31 per cent. of sulphur, were made after mixing the ore with 15 per cent. of iron and manganese oxides. The Mount Lyell type of pot worked well, while in the Huntington-Heberlein pots very poor results were obtained, the product being soft with much "fines," and contained 16.5 per cent. of sulphur; while the Mount Lyell pots yielded an almost solid cake, with an average sulphur content of 8 per cent. It required 12 hours to finish a six-ton charge.

Dynamo Sheet Steel. U. S. PATENT 1,033,352. (*Met. and Chem. Eng.*, x, 563.)—This patent of W. Rübel states that dynamo sheet steel should be free from manganese, silicon, and phosphorus, whilst a slight contamination with carbon and sulphur is less injurious. The addition of spiegeleisen during refining should therefore be avoided, whilst copper, from one to three per cent., is added to the steel to act as a deoxidizer. The refining is done first in a basic and then in an acid converter, or it may be done in the reverse order, or in an electric furnace.

Theory of Absorption and Scattering of α-Rays. C. G. DARWIN. (*Phil. Mag.*, xxiii, 901.)—The α particles from radioactive substances have been thoroughly investigated so that the main features of their motion are now well known. On account of their great mass they go straight, or nearly straight, through matter until their energy is exhausted, the ionization produced being proportional to their loss of energy. It is therefore necessary to adopt a structure for matter such that the α particle pulls electrons out of the atoms containing them, and in so doing loses velocity. The author takes the atomic structure proposed by Rutherford. This considers the atom to consist of a cluster of electrons held by an unknown field of forces round a central charge, which latter is of such amount as to neutralize them and which is supposed to be the seat of the mass of the atom. It is assumed that the electrons in the atom act on the α particle with the ordinary law of inverse-square, and in considering the motion of an α particle the effects of the perturbation of the electron by the rest of the atom are neglected. An equation is deduced relating the velocity of α particles to the distance they have travelled from their source, and this "velocity curve" agrees closely with the experimental curve of Geiger. From the equations the number of electrons in the atom is calculated and found to be intermediate between the atomic weight and its half. The atomic radii are found to decrease with increasing atomic weight. The numbers obtained from the consideration of the absorption of α particles are applied to scattering, and give results in all cases in good agreement with experimental measurements.

Method of Measuring the Speed of Light. C. FÉRY. (*Comptes Rendus*, clv, 823.)—To avoid the difficulty of evaluating the angular velocity of the ordinary rotating mirror in the determination of the speed of light, there is suggested the substitution of a mirror carried on the end of one prong of a tuning-fork. Light from a source at one side is directed on to a screen by a plane plate at an angle of 45°. Through a slit in the screen light passes to the mirror on the fork, and back through the slit to a distant mirror, and then returns. Then when the fork is vibrated the original beam gives two displaced images, A, A', of the slit on the screen, due to the full motion of the prong. But two other images, a, a', at a less distance apart are also obtained, which are due to the slightly displaced positions of the prong when the light has returned from the distant mirror. Thus if the time occupied by the double journey is t, and the period of the fork T, we have $\sin 2\Pi t/T = a\,a'/A\,A'$. Thus for a double distance of 30 k. m. and $T = 0.002$ second, $t = 0.0001$, $a\,a'/A\,A' = \text{Sin } 18° = 0.31$. So if $A\,A'$ were 20 mm., $a\,a'$ would be of the order of 6 mm. The two pair of images could be photographed simultaneously, and thus considerable accuracy would be obtained.

Mill Scale as a Cause of Pitting of Steel Pipes. G. C. and M. C. WHIPPLE. (*Eng. News,* lxviii, 856.)—It is known that accelerated corrosion tests of iron and steel by exposure to strong acids are of small value as an indication of their probable behavior in actual service. Steel pipe-lines usually fail on account of pitting, which ultimately leads to holes and leaks. Mill scale is an important factor in pitting, as is shown by the fact that steel plates which corrode badly when this scale is left on do not pit seriously after the scale is removed. Galvanic survey of the mill scale gives materially different results for wrought iron and for steel, and indicates a much greater homogeneity of the wrought-iron scale. Electrolysis tests show that wrought iron has a less tendency to pit than steel. Copper steels corrode much more slowly than ordinary steels in strong acids, but behave very similarly in water. Since copper does not change the electrical conditions of the scale, it does not affect the tendency to pit. Protection against pitting is best attained by the removal of the scale, but, since this is an expensive process, it appears that efforts should be made to decrease the scale during manufacture, or make it more easily removable, so as to improve its electrical condition.

The Chromium Red Glaze. C. E. RAMSDEN. (*Trans. Eng. Ceram. Soc.,* xi, 196.)—The glazes used were wholly fritted in order to avoid decomposition of the stain in the further fire. The author agrees with all the other investigators except Purdy, that the source of the chromium does not affect the tint. The formula CaO, SnO_2, 0.024 Cr_2O_3, is given for the stain before calcination. If much more chromium is introduced, darker colors are obtained through the formation of insoluble chromates which are not removed in washing. Lime is essential to the production of a good crimson glaze. Magnesia and baryta turn it green and steel-gray respectively. The tint of the calcined powder is not an indication of the color of the resultant glaze. Lead oxide in the glaze is essential for crimson. Silica preserves the red tint under the glaze, while alkalies make it lilac. Borates have but slight influence.

Natural and Magnetic Rotatory Dispersion. T. M. LOWRY. (*Roy. Soc. Phil. Trans.,* ccxii, 261.)—This article treats of: (1) A new test for the optical purity of quartz. (2) An accurate determination of the rotatory dispersive power of quartz for 24 wave-lengths in the visible spectrum. (3) Experiments to test Wiedemann's law. It was found that this law holds good for quartz but not for optically-active liquids.

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THE PRODUCTION AND DISTRIBUTION OF ENERGY.*

BY
SAMUEL INSULL,
President Commonwealth Edison Company, Chicago.
Member of the Institute.

(President Clark, in introducing the speaker, briefly sketched the rapid development of Chicago's electrical interests, giving figures and data, and referred to the active part taken in such development by Mr. Insull.)

Mr. President and Gentlemen: The figures that have been so ably presented are certainly somewhat staggering. I do not think I have ever heard them presented in exactly the same form before. Whilst it is my duty to-night, and my pleasure, to address you on the subject of the generation and distribution of energy—or I will correct that and say " electrical energy "—I have no intention, except in the most incidental way, to refer to the work that we are doing in Chicago. Whenever I have addressed a similar body to this on the subject of the economical production and distribution of energy I have usually referred to the means of production in great cities and the distribution of energy for use in those cities, and have tried to demonstrate that the truly economical method to pursue is the manufacture and distribution of all such energy under one organization. In discussing this subject, especially the last time I addressed myself to it,—namely, before the American

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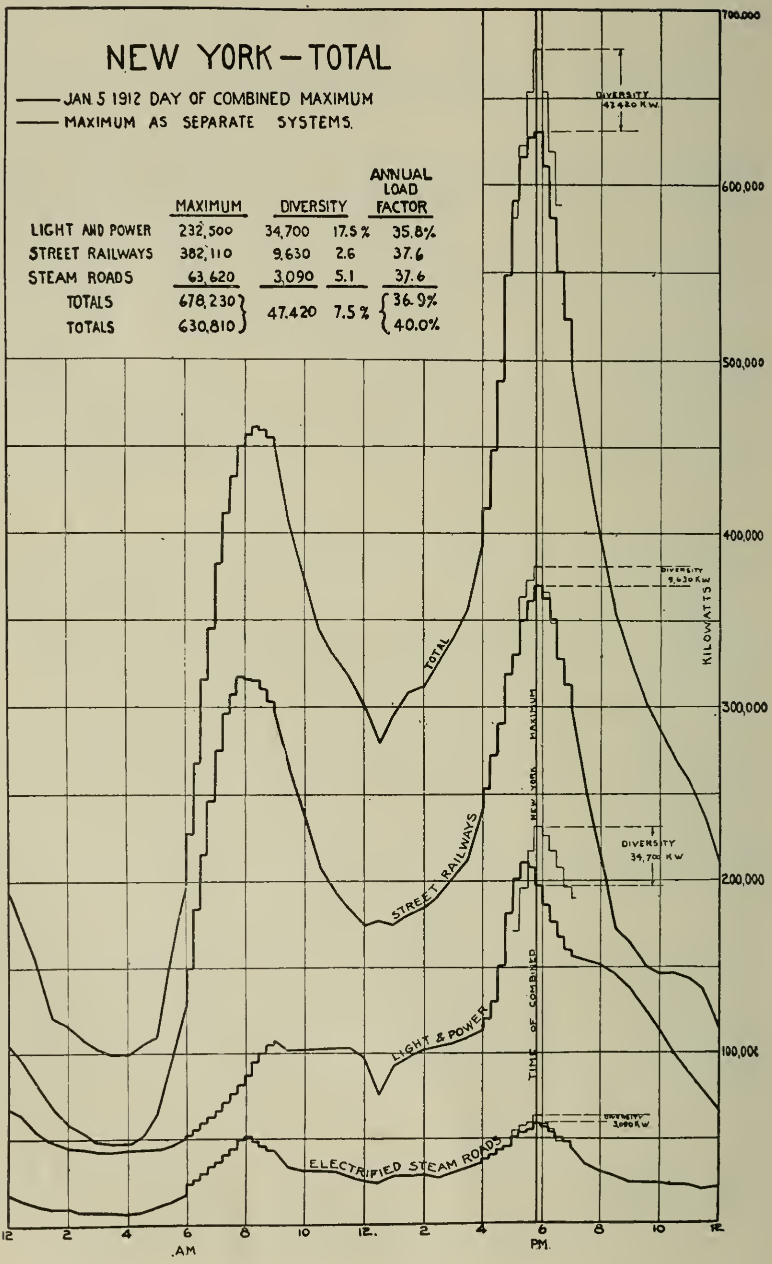
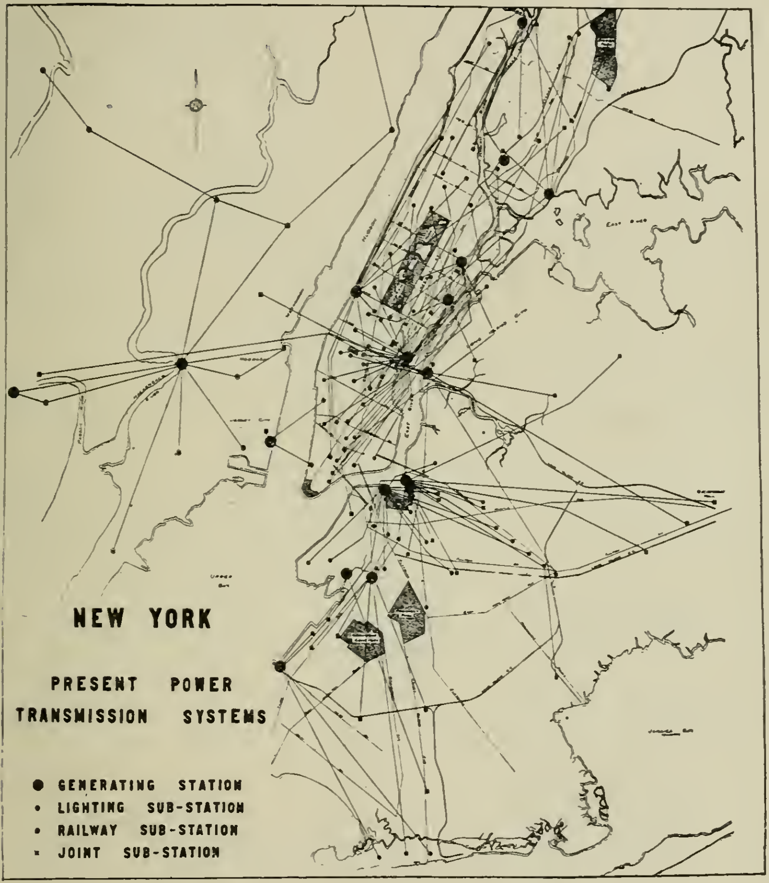
*Presented at the stated meeting held Wednesday, March 19, 1913.

FIG. 1.


NEW YORK—TOTAL
JAN. 5 1912 DAY OF COMBINED MAXIMUM
MAXIMUM AS SEPARATE SYSTEMS.
MAXIMUM | DIVERSITY | ANNUAL LOAD FACTOR
LIGHT AND POWER 232,500 34,700 17.5% 35.8%
STREET RAILWAYS 382,110 9,630 2.6 37.6
STEAM ROADS 63,620 3,090 5.1 37.6
TOTALS 678,230 47,420 7.5% 36.9%
TOTALS 630,810 40.0%
DIVERSITY 47,420 K.W.
DIVERSITY 9,630 K.W.
DIVERSITY 34,700 K.W.
DIVERSITY 3,090 K.W.
TOTAL
STREET RAILWAYS
LIGHT & POWER
ELECTRIFIED STEAM ROADS
TIME OF COMBINED NEW YORK MAXIMUM
KILOWATTS
700,000
600,000
500,000
400,000
300,000
200,000
100,000
12
2
4
6
8
10
12.
2
4
6
8
10
12.
A.M.
P.M.

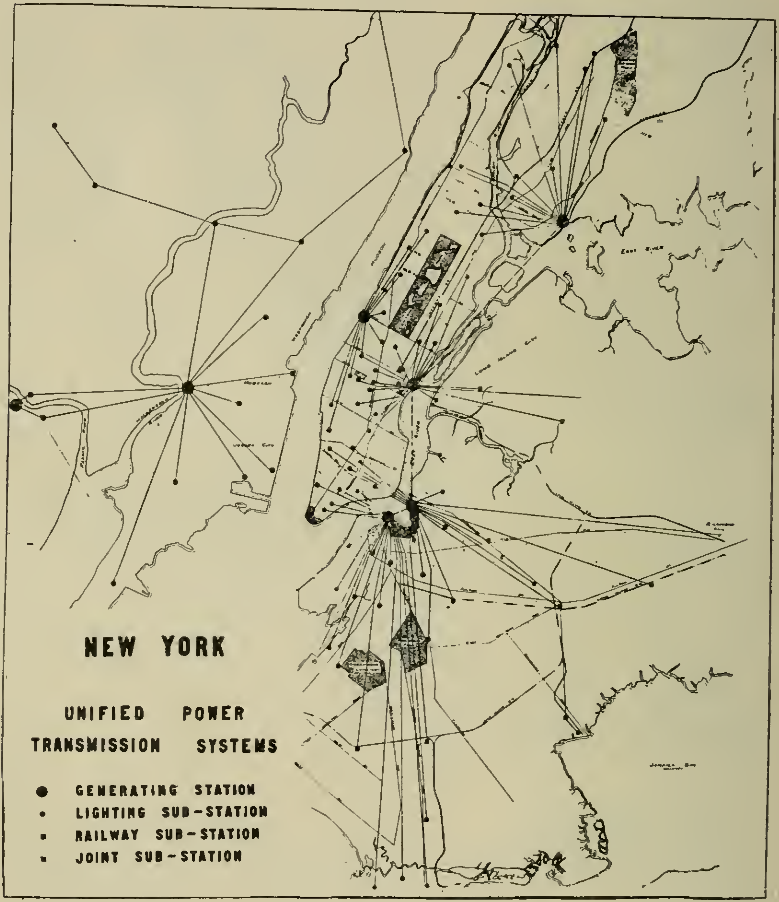
Institute of Electrical Engineers, about a year ago,—I have referred to the necessity of having very large prime movers, a necessity which undoubtedly exists, in order to get economical production in large cities; but this evening I propose to give my

Fig. 2.



attention—and to ask you to give your attention also—to exactly the opposite viewpoint. I propose to take the smallest prime movers that I have had anything to do with in the smallest generating stations in the rural and agricultural territory of Illinois, and, starting from that point, to draw your attention to the various uses to which electrical energy can be put in performing the various duties required of it, for the benefit of the local farming community, the small country towns surrounded by such farming communities, the lowlands of the State requiring

FIG. 3.



drainage, the mines of the State requiring electrical power, and the interurban roads traversing the State and requiring energy for the propulsion of their cars. If time will permit, I propose to endeavor to show you that the true economic method of the production and distribution of energy for all these purposes, and for some other purposes to which I will incidentally refer, necessarily involves, so far as a State-wide service is concerned, concentration of production, concentration of distribution, and, if you may choose to call it so, monopoly of administration of the business of producing and distributing electrical energy.

Just by way of introduction, I will throw a few slides on the screen. Fig. 1 gives some estimates of the amount of energy required for New York, and possibly an area within twenty or thirty miles around, from which you will see that at the present time it takes about 678,000 kilowatts to take care of that area.

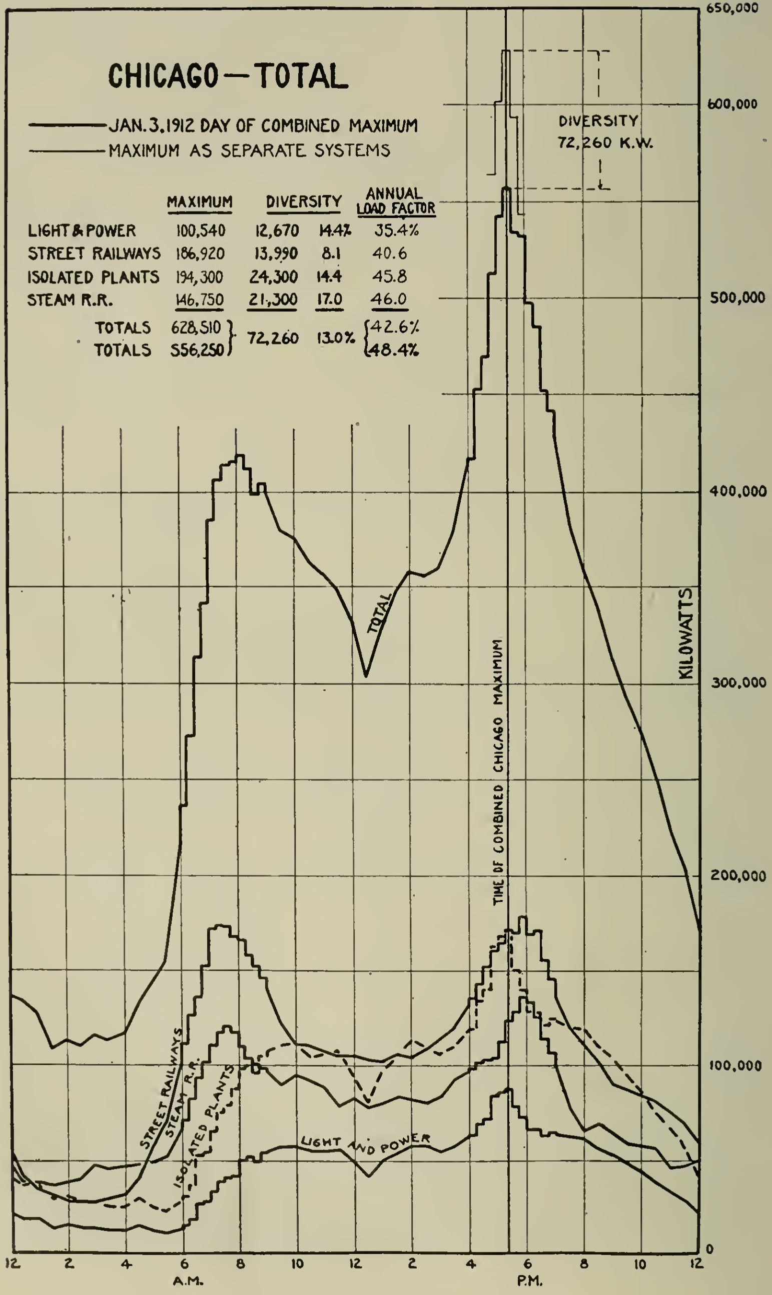
You see, the load factor is 36.9 per cent.; the diversity is about 7.5 per cent., and if this energy were all produced under one organization, there would be a maximum of only 630,000 kilowatts to provide capacity for, and the load factor would be increased to 40 per cent.

Fig. 2 shows the general distribution in and around the city of New York, with all the users of electrical energy operating different systems.

The next chart, Fig. 3, shows a unified power production and distribution, a comparison of the two maps illustrating the possible consolidation of a number of power stations, some of them small, into a reduced number of large, well-located stations, and the elimination of duplication and waste in transmission lines, which in the former chart crossed and recrossed each other.

The next chart, Fig. 4, shows the total business of Chicago, including the light and power, the street railways, the load carried by isolated plants, and the estimated amount if the railroad terminal system of Chicago were electrified. The total amount required is 628,000 kilowatts, with a diversity factor of 13 per cent. and an annual load factor of 42 per cent. If that were all produced under one organization, the maximum amount required at any one time would be only 556,000 kilowatts and the load factor would be increased to about 48 per cent. I am inclined to think that the figures on percentage of diversity given there are nearer correct than those given in the New York chart. What you see there is what we are working toward in Chicago. The light and power figures and the street railway figures are a year old. We hope, as the time comes on for steam railroad electrification, that the steam railway people will see that the

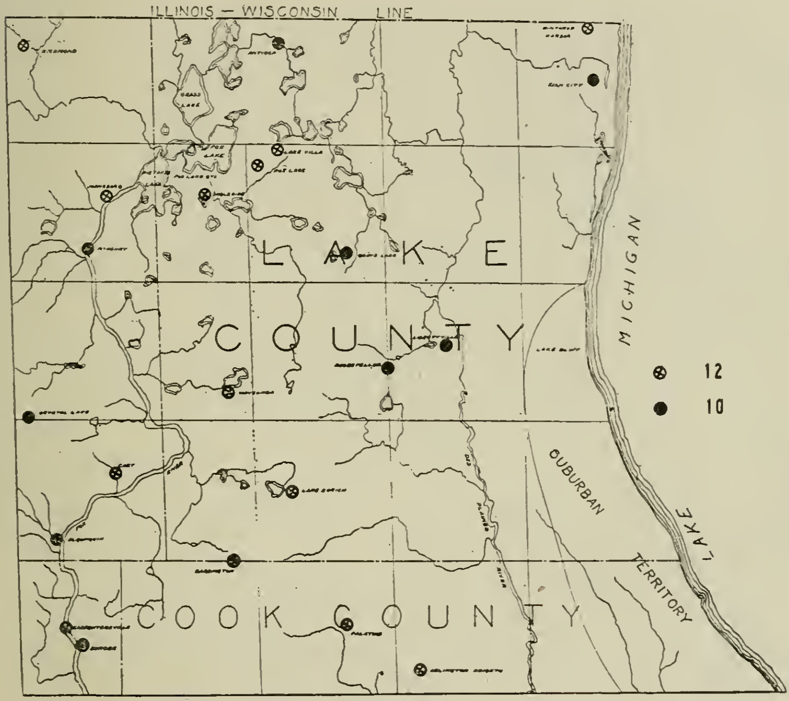
FIG. 4.



	MAXIMUM	DIVERSITY		ANNUAL LOAD FACTOR
LIGHT & POWER	100,540	12,670	14.4%	35.4%
STREET RAILWAYS	186,920	13,990	8.1	40.6
ISOLATED PLANTS	194,300	24,300	14.4	45.8
STEAM R.R.	146,750	21,300	17.0	46.0
TOTALS	628,510	72,260	13.0%	42.6%
TOTALS	556,250			48.4%

business of manufacturing energy is altogether a different proposition from the business of managing and operating transportation companies, and the old adage that the "shoemaker should stick to his last" is not a bad maxim for steam railroad men and electrical men to follow.

Fig. 5.



YEAR 1910

⊗ TOWNS OF OVER 300 POPULATION WITHOUT ELECTRIC SERVICE

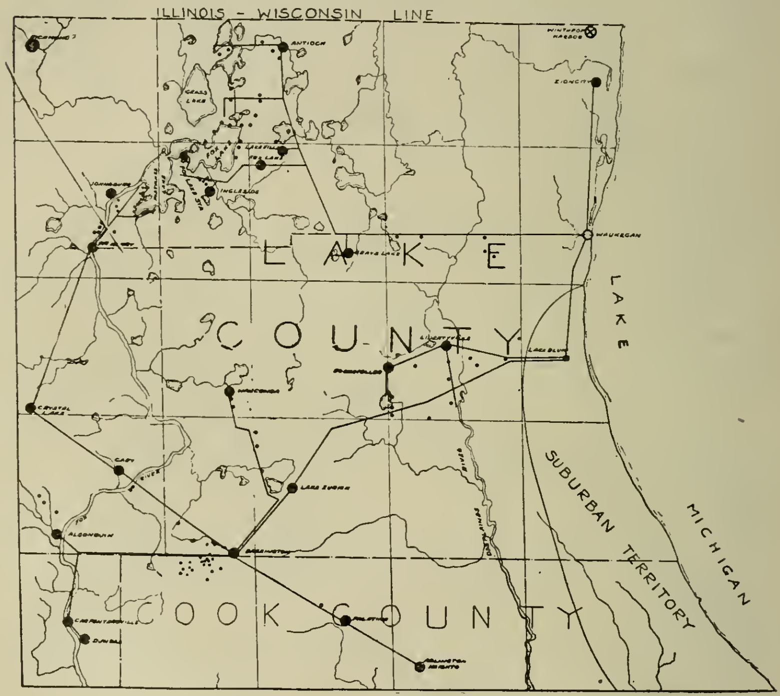
● TOWNS WITH ELECTRIC SERVICE (AT NIGHT ONLY)

I now come to the main part of my lecture. The reason I have chosen the Lake County district and surrounding territory, shown in Fig. 5, which is the extreme northern corner of Illinois, facing on Lake Michigan, is that this probably is the poorest territory for the purpose of central station distribution that it has been my fortune to operate in. The plants were acquired in that territory in the year 1910.

The towns marked by a crossed circle are twelve in number, with a population of 7886. Those marked by a black circle are the only towns in the territory which had electric service, and that at night only.

The next chart, Fig. 6, shows the condition two years later, in 1912. There are only two places in the county without electric service. There are twenty towns served, having a population of 22,188 people, and there are 125 customers, which are mostly farmers, outside the corporate limits of any of the villages in that territory.

FIG. 6.



⊗ TOWNS OF OVER 300 POPULATION WITHOUT ELECTRIC SERVICE, 2, POPULATION 993.

● TOWNS OF OVER 300 POPULATION WITH 24-HOUR ELECTRIC SERVICE, 20, POPULATION 22,188.

· CUSTOMERS OUTSIDE OF TOWNS WITH 24-HOUR ELECTRIC SERVICE, 125.

Fig. 7 shows the distribution system, outside of one of the villages, which serves a number of farms. Some two years ago, when that territory was taken over, an isolated plant was acquired which a gentleman farmer who had a very large farm in this vicinity had installed and which supplied a few of his neighbor farmers in addition to his own requirements, forming the nucleus of the rapidly-developing load of this territory. The main circuit is installed on the same poles with the transmission lines.

FIG. 7.

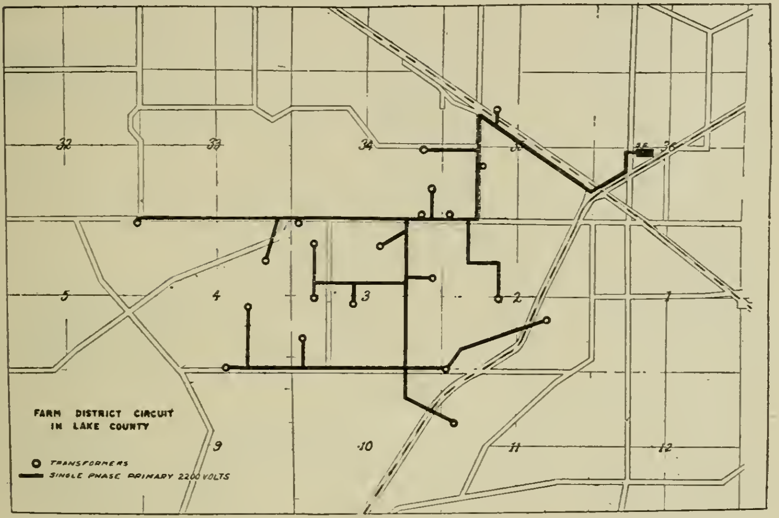
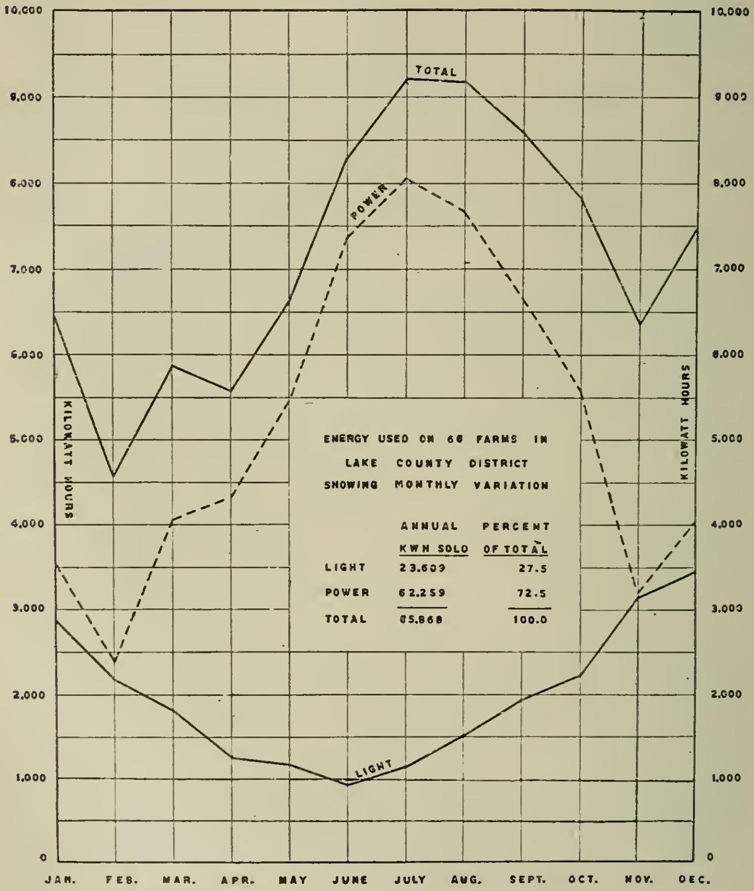


Fig. 8 shows the monthly variation in energy used on 68 farms. The annual kilowatt-hours for light were 23,609 and for power 62,259 kilowatt-hours. The lighting was 27.5 per cent. of the total, and the power 72.5 per cent. The highest consumption comes in the middle of summer, which is the opposite time to the highest consumption in the adjacent towns.

Fig. 9 shows two typical farm-load diagrams, which indicate the same as the previous chart—that rural or farm load has its maximum in summer; they are plotted from actual readings taken at the sub-station. The maximum occurred on the day before the Fourth of July, and the unusually high evening lighting peak is explained by assuming that the city people came out the evening before to spend the Fourth at their country places.

While these curves may not be entirely representative of general farming load, because there are several large farms owned by wealthy city people whose freer use of electricity probably influences the total, nevertheless they include a large number of average size farms and farmers of average means. The curves are probably an indication of the development that is possible for this class of business.

FIG. 8.



ENERGY USED ON 68 FARMS IN LAKE COUNTY DISTRICT SHOWING MONTHLY VARIATION

	ANNUAL KWH SOLD	PERCENT OF TOTAL
LIGHT	23.609	27.5
POWER	62.259	72.5
TOTAL	85.868	100.0

Table I gives some actual statistics on these same 68 farms. The figure of 2.4 horsepower for motors connected is very low indeed, and should eventually increase several times as this business is developed.

TABLE I.

DATA ON LAKE COUNTY FARMS.

Total number of farms	68
Average acres per farm	162

	Per farm.	Per acre.
Incandescent lamps in 50-watt equivalent	30.5	..
Motors in horsepower	2.4	..
Total connected load in kilowatts	3.3	..
Annual light kilowatt-hours	347	2.14
Annual power kilowatt-hours	916	5.65
Total kilowatt-hours	1263	7.79
Income from light	$41.60	26c
Income from power	55.90	34
Total income	$97.50	60c

TABLE II.

COMPARISON OF COST OF ENERGY.

Lake County District.

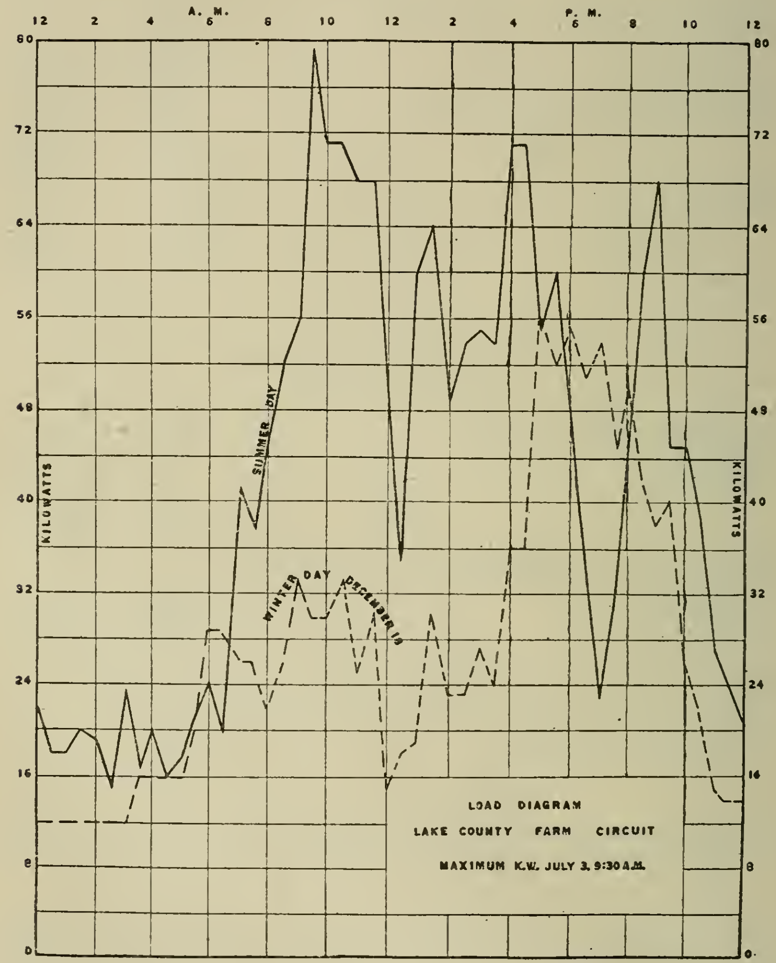
	1910	1912
Investment per kilowatt of maximum		
Generating station	$178	$122
Sub-station	..	70
Transmission	..	190
Total	$178	$382
Fixed charge on investment per kilowatt of maximum	$20.85	$42.60
Maximum kilowatts	573	963
Load factor	14.6 %	28.9 %
Costs per kilowatt-hour at local plant or sub-station		
Fuel	2.04c	.61c
Other operating, including sub-station and transmission	3.42	.56
Fixed charges on investment	1.62	1.68
Total costs	7.08c	2.85c

Showing a saving in supplying this district from unified power supply and transmission system of 4.23 cents per kilowatt-hour.

Fig. 10 shows a comparison of two winter-day load diagrams prorated to the same maximum, in order to show the growth of the day load in the Lake County territory and the consequent improvement in the load diagram and load factor as compared with the average local town plant, of which the diagram of 26 towns recently taken over is typical.

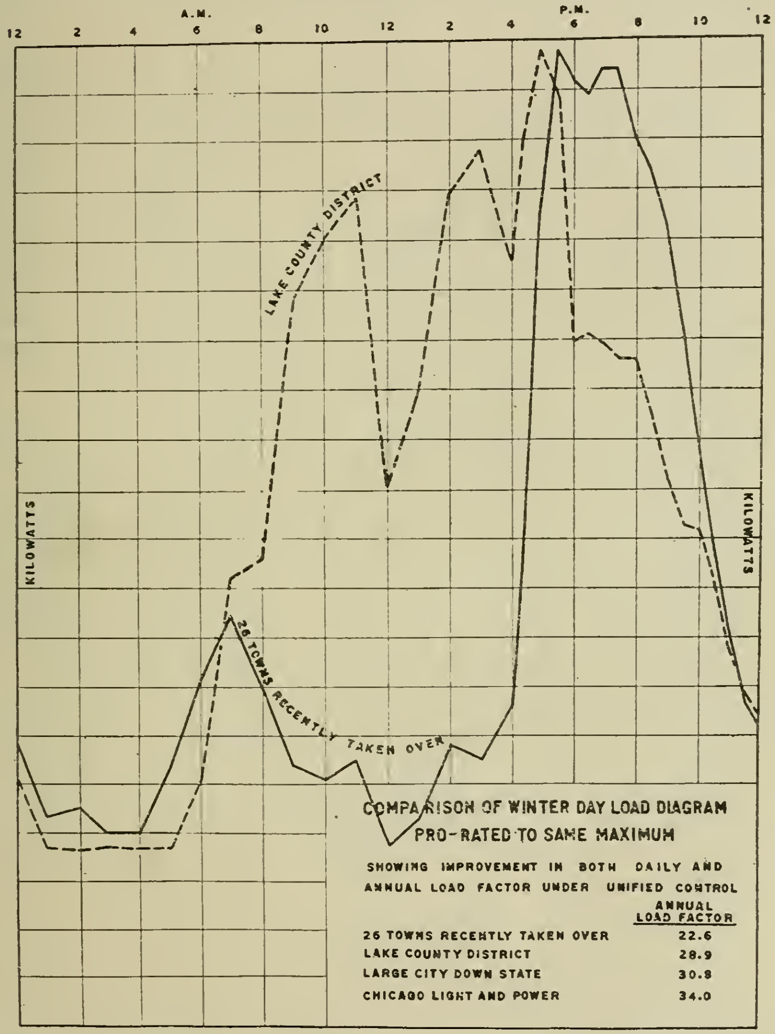
I am dwelling at some length on this particular territory because it is not a manufacturing district and there are very few towns in it, as the suburban district tributary to Chicago, as shown by the map, has been cut out of the figures.

FIG. 9.



The annual load-factor figures show what can be done in the way of improvement by unified control. The annual load factor of 26 towns recently taken over was only 22.6 per cent., while the load factor of the Lake County district, after two years of unified control, has been brought up to 28.9 per cent., and, for comparison, one of the large cities down the State has a load

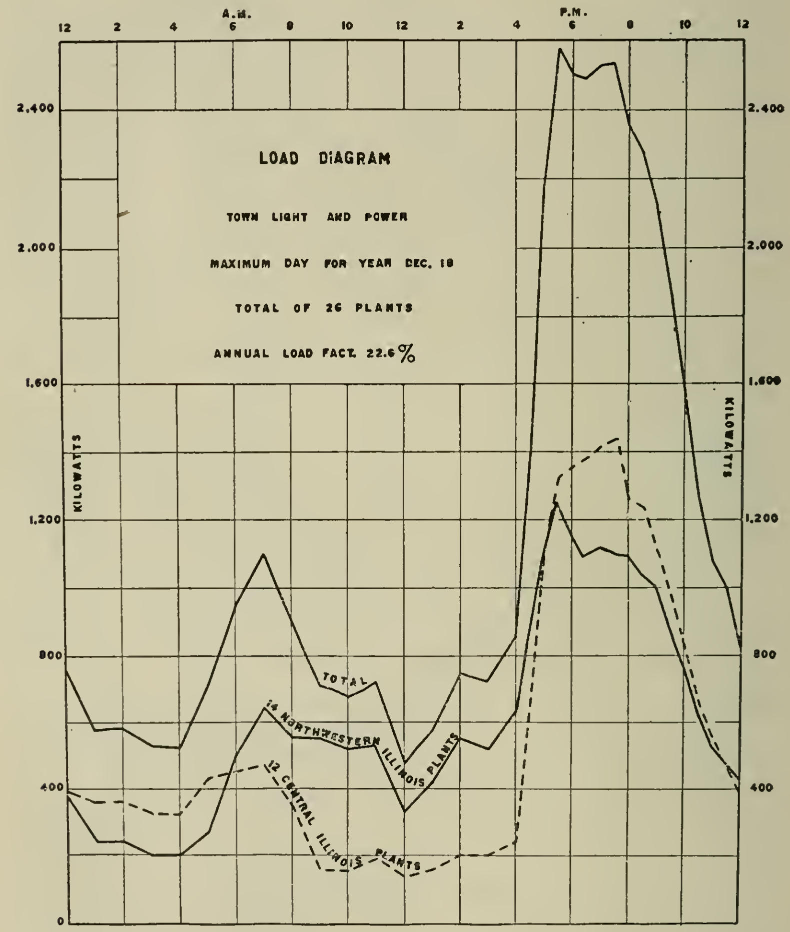
Fig. 10.



factor of 30.8 per cent., and the Chicago light and power annual load factor, exclusive of railway, is 34 per cent.

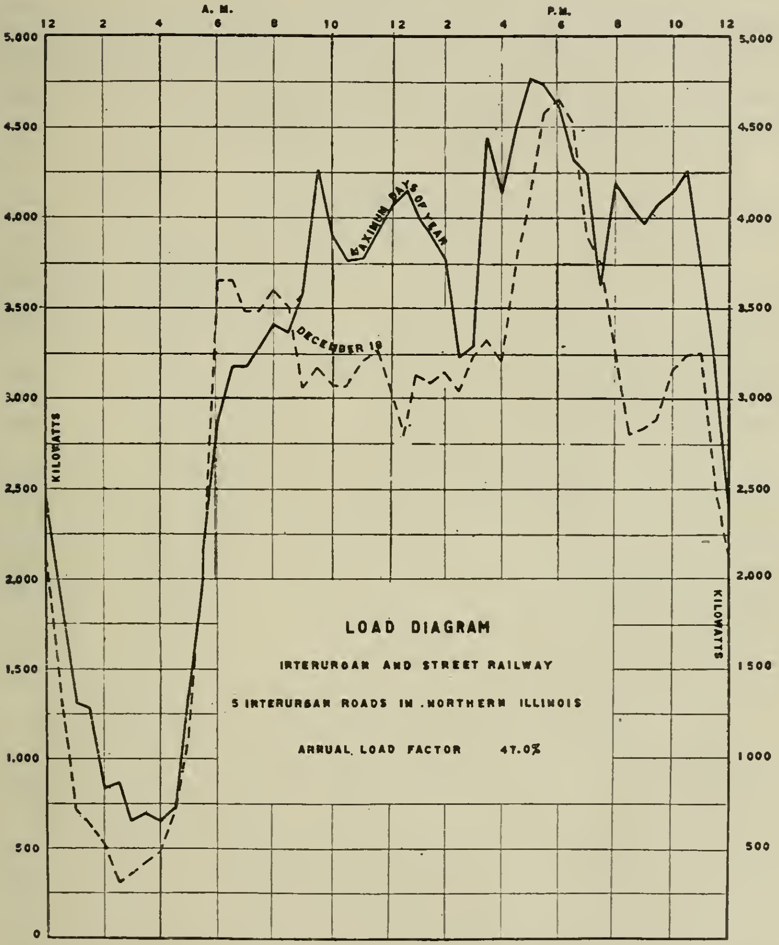
Table II gives a comparison of the cost of energy, investment cost, and operating cost under the old plan, when there were a few isolated central stations in small towns, with the cost of energy for the same territory two years later from a modern station, transmission and sub-station system. The total cost of these old stations, not including the distribution systems used in the towns, was $178 per kilowatt. In abandoning these stations and building transmission lines from a town on Lake Michigan, where we could get cheap energy, and building local sub-stations, you will see the cost was brought up to $382 per kilowatt. Under the old scheme the fixed charges for invest-

FIG. 11.



ment per kilowatt was $20.85, and under the new scheme two years later the charge was $42.60. These figures would seem to indicate rather a prohibitive proposition, so far as the new

FIG. 12.



scheme of unification is concerned, as compared with small isolated stations. But if you go a little lower down you will see that under the old scheme we had only 14.6 per cent. load factor, whereas with a unified system of power we had 28.9 per cent. load factor.

Applying these respective load factors to the fixed charges on investment you will find that the fixed charge per kilowatt-hour figures out only a mere fraction higher under the new scheme, owing to the great difference in load factor.

If you go still lower down you will find that the fuel cost under the old scheme is 2.04 cents, whereas under the new scheme it is .61 cent. The sub-station and transmission operating and other station operating expenses are relatively even lower under the new scheme than under the old.

TABLE III.

Lake County District.

	Separate management in each town. 1910 conditions	Unified power and transmission system 1912 conditions
Population served	15,395	22,188
Number of towns served	10	20
Number of customers	1,422	3,457
Connected load in killowatts	2,033	4,503
Kilowatt-hours sold	699,574	1,898,978
Kilowatt-hours sold per capita	45	86
Income	$62,371	$136,694
Income per kilowatt-hour	8.9c	7.2c
Income per customer	$43.86	$39.54
Income per capita	$4.05	$6.16
Maximum kilowatts	573	963
Annual load factor	14.6%	28.9%

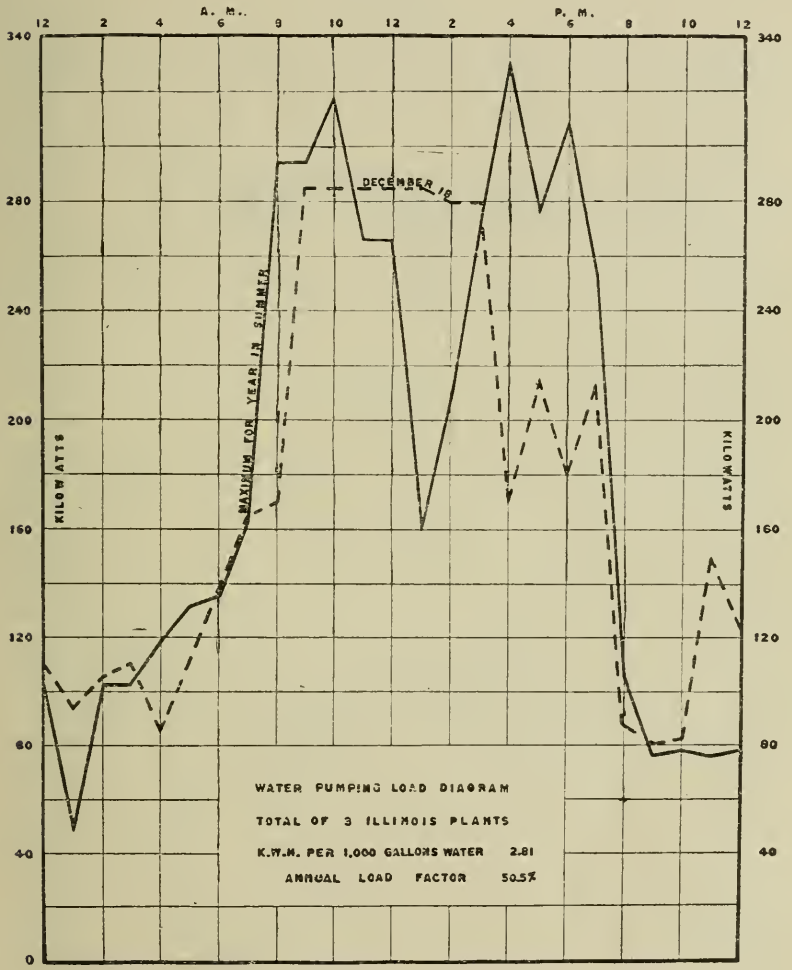
These operating costs include not only the station cost but the operation and maintenance of transmission lines and sub-stations and the losses in transmission from station to sub-station, also the conversion loss in the sub-station, but the figures do not include in either case any local distribution expense or general expense. So that when you come to total up these figures, notwithstanding that apparently you start out with over twice the investment, you will find your base cost per kilowatt-hour at the local lighting plant or sub-station under the old plan was 7.08 cents per kilowatt-hour, and under the new plan 2.85 cents, showing a saving of 4.23 cents per kilowatt-hour.

Table III gives us some further figures on this same Lake County territory.

Fig. 11 is a load diagram showing general light and power for the maximum day.

These are the actual load curves for 26 plants, and it will be noted that those for northwestern Illinois show a very much better day load than those for central Illinois, probably due to the fact that the northwestern Illinois properties were acquired about a year earlier and the power load has been better devel-

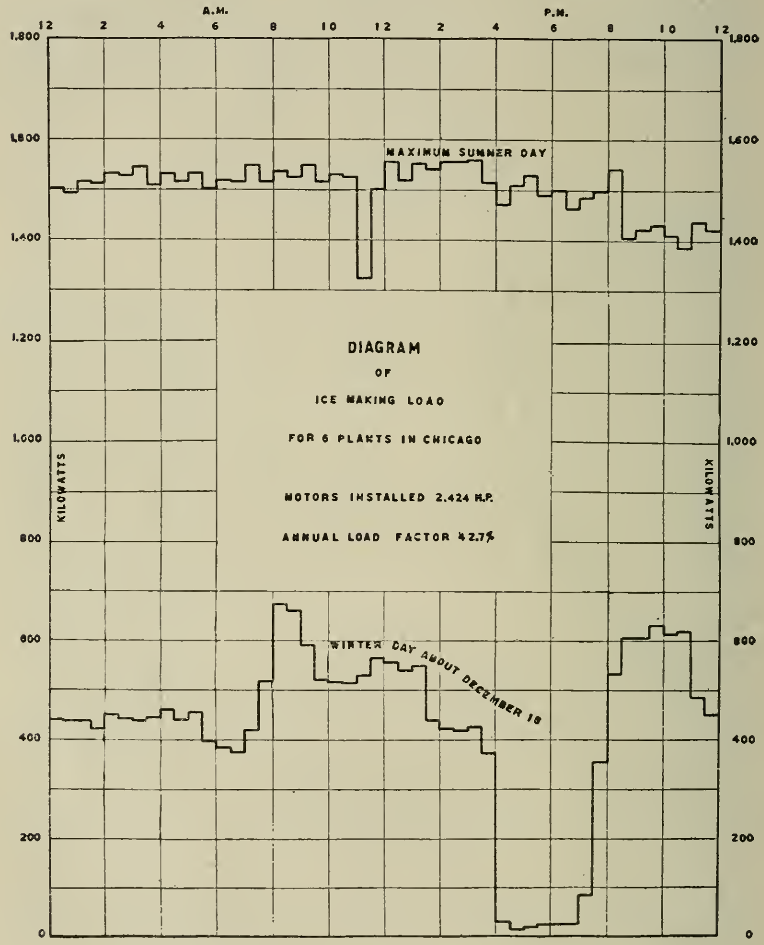
FIG. 13.



oped. The Lake County diagram still further emphasizes this point.

The total light and power diagram for the State has been prorated from this diagram, and, while this probably gives us the approximate diagram and kilowatt-hour output for the State for this present winter, the improvement in load factor and increase in kilowatt-hour output should be very rapid; that is, we might have estimated the total light and power for the

FIG. 14.



State based on the Lake County diagram, which would have given a greater output and better load factor and which would probably be a very close estimate to the actual figures.

Fig. 12 is the load diagram of five interurban roads in northern Illinois. The annual load factor is 47 per cent. The maximum load comes on a summer holiday.

The heavy fluctuations of interurban load require, in case of separate power plant for interurban supply only, a greater reserve capacity than if supplied from a station serving several classes of business.

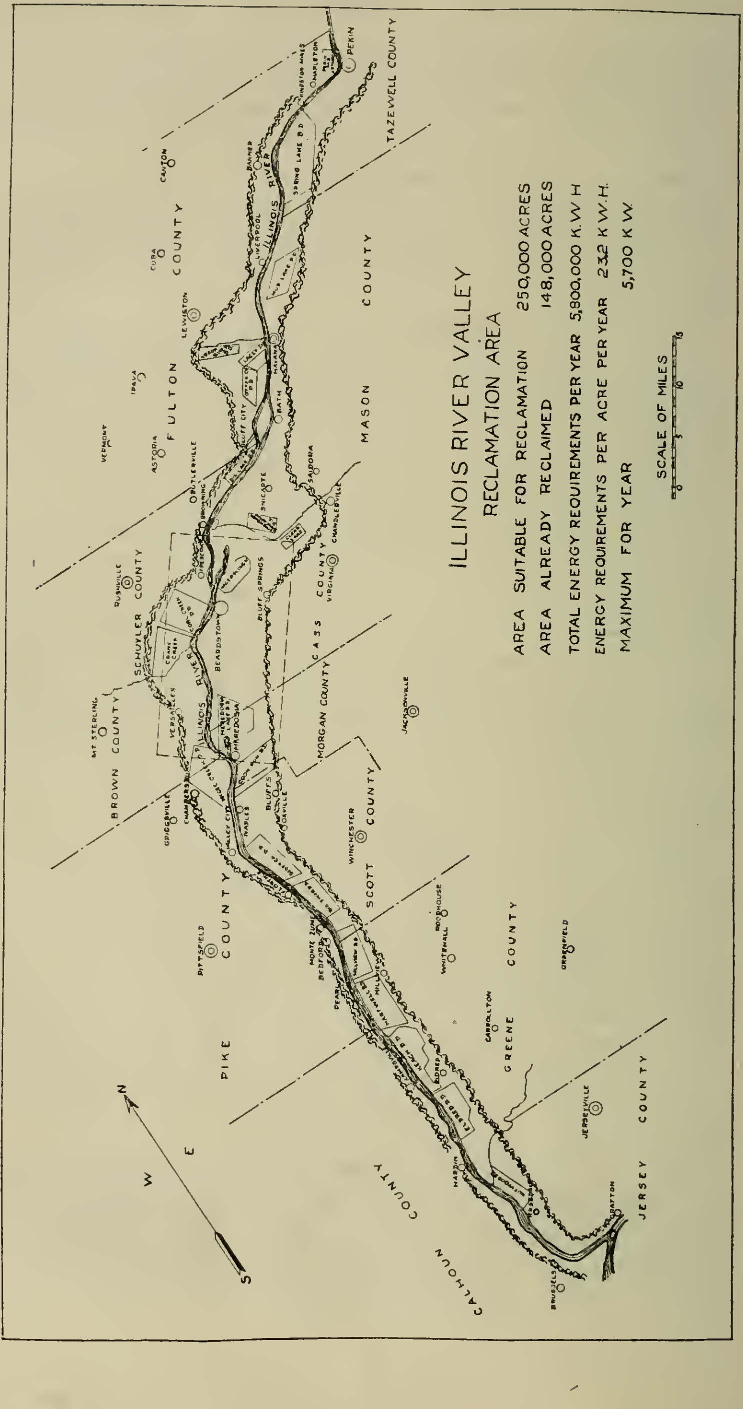
The total kilowatt-hour output for the 62 interurban and street railways in the State, outside of Chicago, has been estimated, from these five and two other roads, on three different bases,—that is, per passenger, per car-mile, and per car,—and the three figure out very close. The total curve for the State has been prorated from these curves using this output.

Fig. 13 shows a water-pumping load diagram of three northern Illinois plants, the kilowatt-hours per thousand gallons amounting to 2.81. You will see the maximum comes in the summer, and it is possible to so arrange this production that it is practically off-peak business. Most of the small water-pumping plants in the small central western towns pump to a reservoir in an elevated position, so that the question of exactly when the pumping shall take place is not a serious matter, except in a case of a serious fire in a town or village. As a rule, that class of business gives a load factor of about 50.5 per cent.

Fig. 14 shows a diagram of an ice-making load for six plants in Chicago. The motors installed amount to 2424 horsepower, and the annual load factor is 42.7 per cent. Contracts are made so that the operations shall cease at the time of maximum load for a period of a few hours per day for four or five months in the winter, which is not objectionable in that business. The reason we have taken these six plants is because they are about of a size that is generally used in the small towns throughout the State, and therefore the load curves would apply equally well to the country as to the city.

Fig. 15 illustrates an entirely different class of business. These maps and the data that I give here and on the next two or three slides refer to the Illinois River drainage district, and we present them as an interesting illustration of the use of electricity from a transmission system.

FIG. 15.


ILLINOIS RIVER VALLEY
RECLAMATION AREA
AREA SUITABLE FOR RECLAMATION 250,000 ACRES
AREA ALREADY RECLAIMED 148,000 ACRES
TOTAL ENERGY REQUIREMENTS PER YEAR 5,800,000 K.W.H
ENERGY REQUIREMENTS PER ACRE PER YEAR 23.2 K.W.H.
MAXIMUM FOR YEAR 5,700 K.W.
SCALE OF MILES
0
5
10
15
ILLINOIS RIVER
TAZEWELL COUNTY
FULTON COUNTY
MASON COUNTY
SCHUYLER COUNTY
BROWN COUNTY
CASS COUNTY
MORGAN COUNTY
SCOTT COUNTY
PIKE COUNTY
GREENE COUNTY
JERSEY COUNTY
CALHOUN COUNTY
PEKIN
CANTON
CUBA
LEWISTON
IPAVA
VERMONT
ASTORIA
BUTLERVILLE
BROWNING
RUSHVILLE
MT STERLING
VERSAILLES
CHAMBERSBURG
GRIGGSVILLE
PITTSFIELD
BEARDSTOWN
BANNER
LIVERPOOL
HAVANA
BATH
SNICARTE
SAIDORA
CHANDLERVILLE
VIRGINIA
BLUFF SPRINGS
MEREDOSIA
NAPLES
VALLEY CITY
BLUFFS
OXVILLE
JACKSONVILLE
WINCHESTER
MONTE ZUMA
BEDFORD
PEARL
ROCKHOUSE
WHITEHALL
GREENFIELD
CARROLLTON
ELDRED
HARDIN
JERSEYVILLE
GRAFTON
BRUSSELS
SPRING LAKE D.D.
BLUFF CITY
N
S
E
W

Between the bluff lines, which run approximately parallel to the river, is a wide flat valley which is subject to overflow at times of high water, but when reclaimed by building dikes around suitable areas and draining and pumping out the surplus water, extremely fertile land is made available.

The load factor of the business by itself, being less than 12 per cent., does not warrant the installation of a generating and transmission system for this supply by itself, but when combined with other uses of electricity in the same territory it is valuable business, as it is altogether off-peak.

A cheap power supply should greatly accelerate the reclamation of swamp and overflow land throughout the country.

Fig. 16 shows in detail one section of the preceding map. You will see the lines of the bluffs on either side, and the patches there are the various districts which have already been reclaimed or which it is proposed to reclaim.

The pumping station is always located at the best point in the district to drain all the land and to return the water to the river. It is quite an advantage sometimes to locate more than one pumping station in a district, because of topographical conditions involving quicker and better drainage. This is perfectly practicable with motor drive, while it is usually out of the question to build two steam plants in the same district.

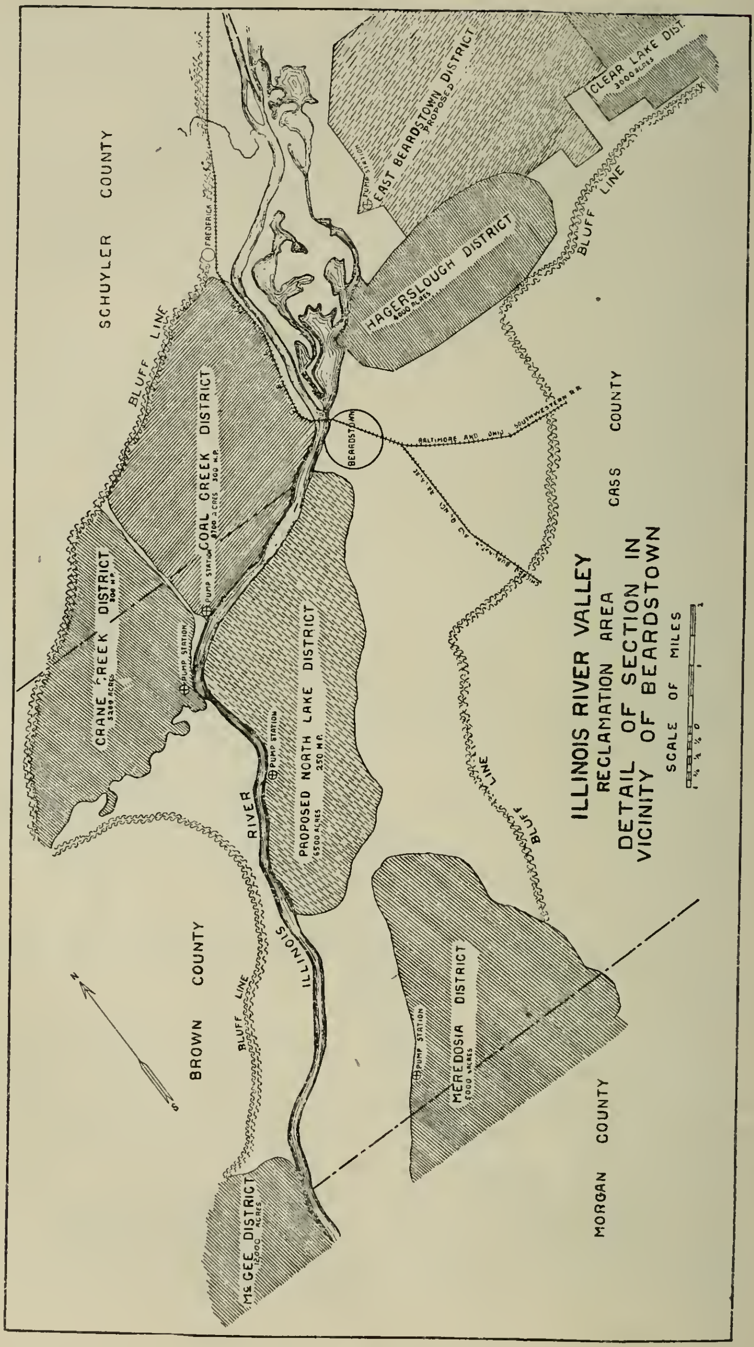
A co-operative plant and transmission, as was planned for the entire district, involves an expenditure of approximately $1,335,000, while a public utility company with transmission lines practically along the entire valley, in order to supply local towns, can take care of this same business at an expenditure of not over $411,000.

The cost of co-operative output per kilowatt-hour figures at least 3 cents higher than the cost of supply to a public utility company.

Fig. 17 shows the monthly variation in precipitation and energy requirements. The high point there is partly owing to the melting of the winter precipitation stored in the form of snow and ice, and partly owing to high water, requiring greater energy to pump against.

Fig. 18 is an estimated load diagram of that class of business. In the winter days it is not an important matter. The contracts are drawn so that we have a right to cut off the sup-

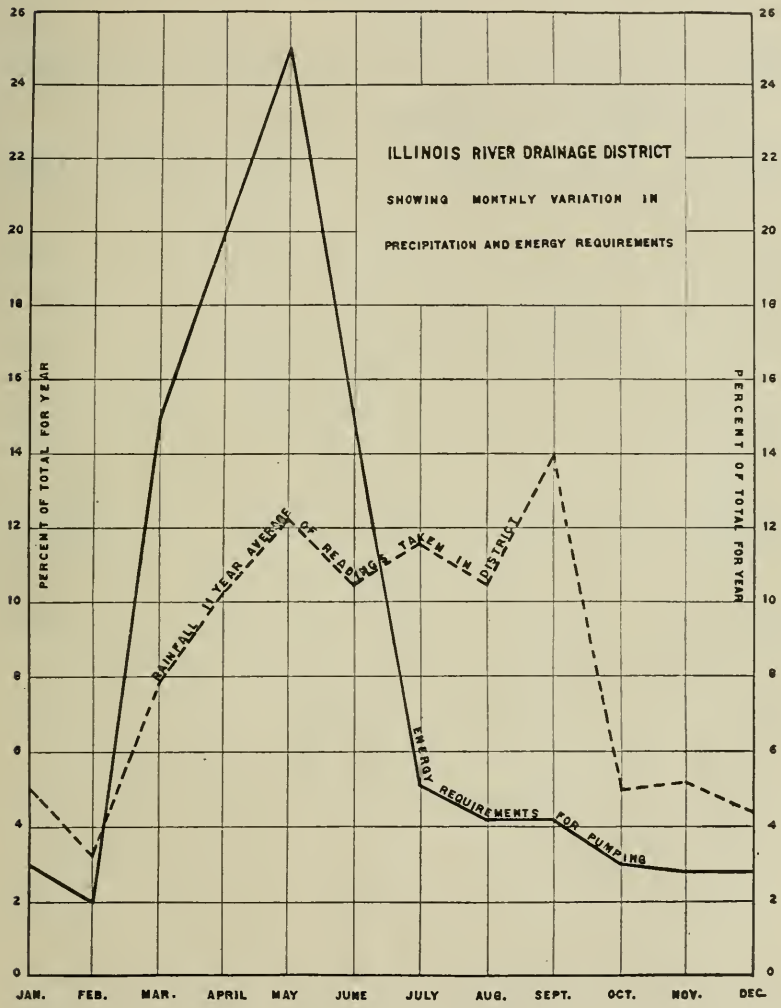
FIG. 16.


SCHUYLER COUNTY
BLUFF LINE
FREDERICK
PUMP STATION
EAST BEARDSTOWN DISTRICT
PROPOSED
CLEAR LAKE DIST.
3000 ACRES
HAGERSLOUGH DISTRICT
4600 ACRES
BLUFF LINE
BEARDSTOWN
BALTIMORE AND OHIO SOUTHWESTERN R.R.
COAL CREEK DISTRICT
8700 ACRES 300 H.P.
PUMP STATION
CRANE CREEK DISTRICT
3200 ACRES
300 H.P.
PUMP STATION
PROPOSED NORTH LAKE DISTRICT
6500 ACRES 250 H.P.
PUMP STATION
ILLINOIS RIVER
CASS COUNTY
ILLINOIS RIVER VALLEY
RECLAMATION AREA
DETAIL OF SECTION IN
VICINITY OF BEARDSTOWN
SCALE OF MILES
BLUFF LINE
N
S
BROWN COUNTY
BLUFF LINE
MEREDOSIA DISTRICT
5000 ACRES
PUMP STATION
MORGAN COUNTY
McGEE DISTRICT
12000 ACRES

ply for a period of three hours, and consequently it becomes absolutely an off-peak business.

The coal mining load, Fig. 19, has been estimated by mining

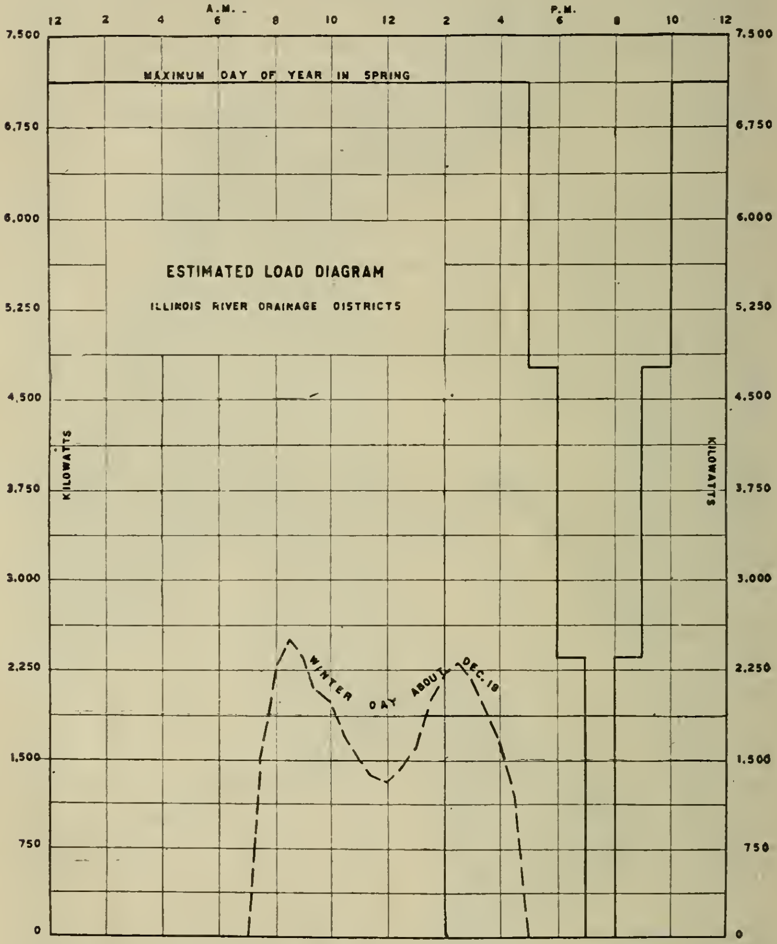
FIG. 17.



engineers from their experience (across the whole State of Illinois) and actual load diagrams of two mines which are operated largely electrically. These data indicate about 1.63

kilowatt-hours at the mine per ton of coal produced, and we applied this figure to the total tonnage of the State, which is approximately 50,000,000 tons, produced by 845 mines. Of these, 586 mines, producing about 5,000,000 tons, are eliminated as local mines too small to equip electrically. There is added the estimated load for some forty washing and re-screening plants, and then transformer and line losses. The load factor for the individual mines figures about 20 per cent., due to the fact that

FIG. 18.



the mines are operated only a little over one-half of the number of days per year; but there is considerable diversity between the mines, as one day a mine or group of mines shuts down, and another day some others, so that the load factor for all the mines is brought up to about 25.6 per cent. Further, the diversity is large, as it is practically off-peak business, the men all quitting work at 4 P.M. and being out of the mines before 4.30 P.M., that being earlier than the average evening load for other purposes in the territory.

FIG. 19.

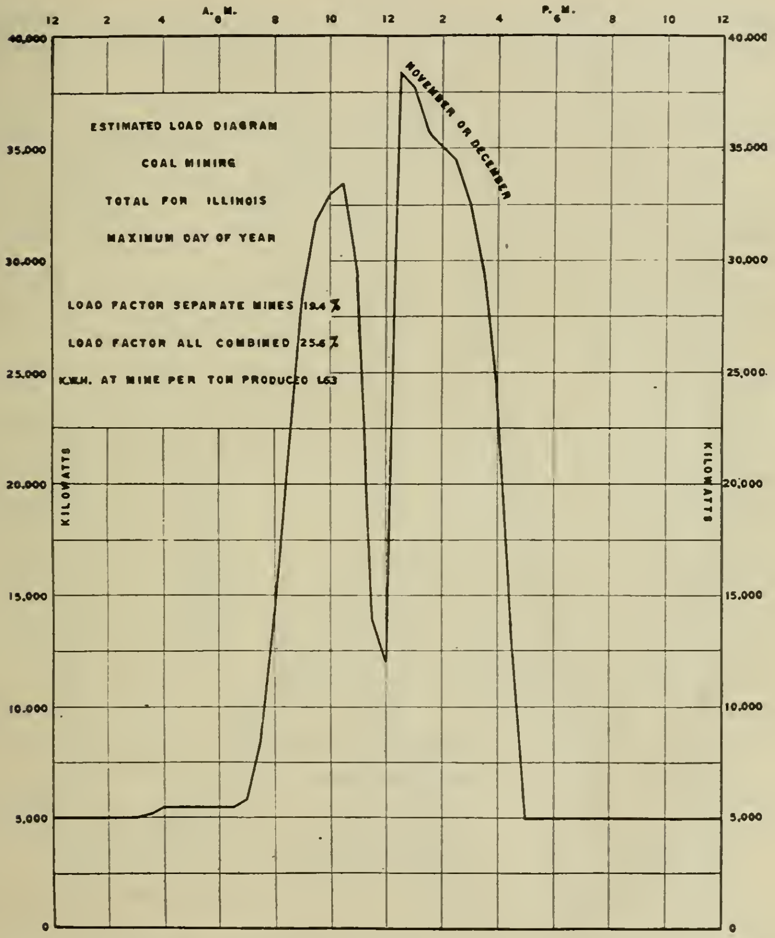
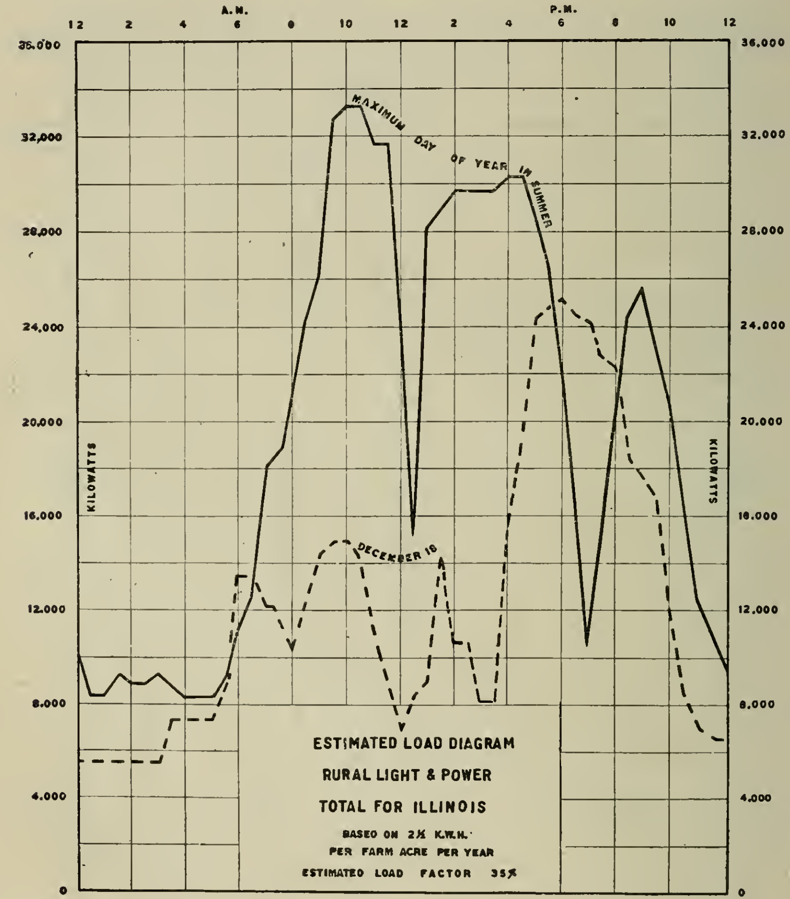


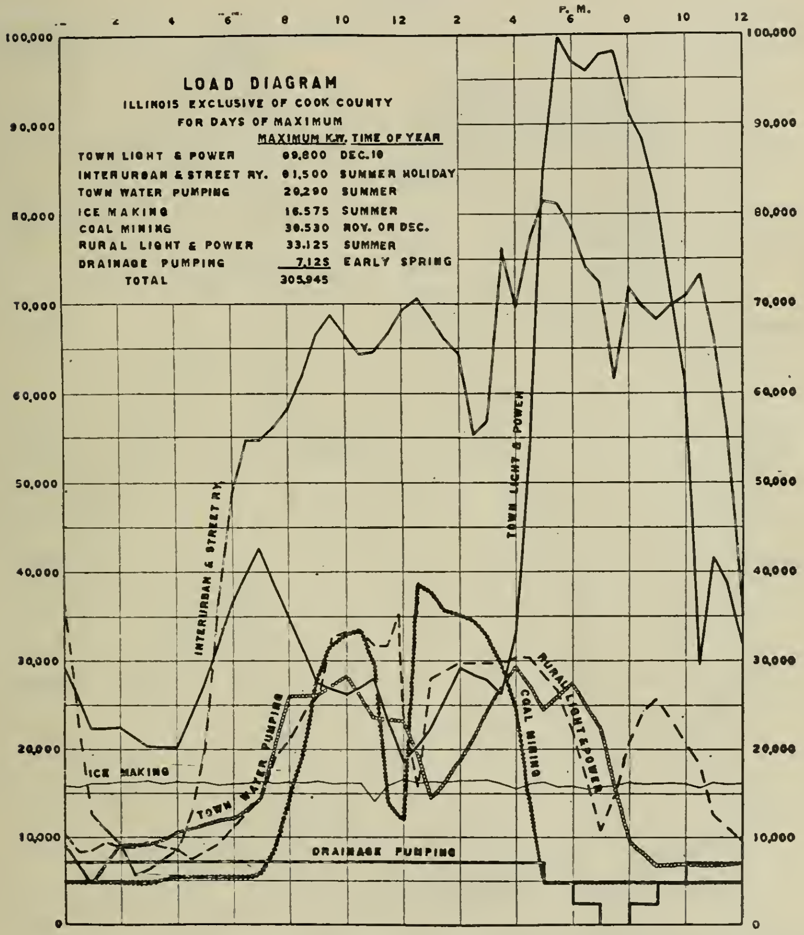
Fig. 20 shows a load diagram of the total power for rural Illinois based on 2.5 kilowatt-hours per farm acre per year. We have taken the Lake County figures of 7.79 kilowatt-hours per farm acre and cut it two-thirds, so as to be absolutely safe in our figuring. The Lake County figures, to my mind—as we had only two years to make any development—are very low indeed, and I believe that the maximum demand for an ordinary farm will greatly exceed in future years 7.79 kilowatt-hours per acre, so that we cannot go very far wrong, so far as minimum

FIG. 20.



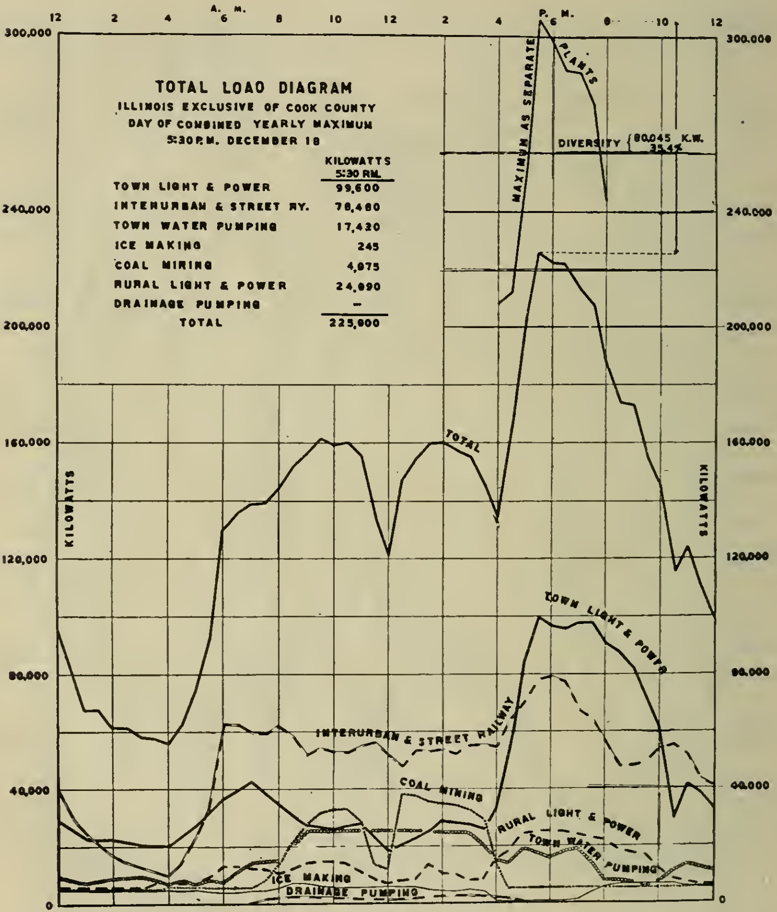
possibilities are concerned, if we take one-third of what we are doing and assume that to be the consumption per farm acre. You will notice the load factor is 35 per cent., and that the maximum, as I told you before, comes in the summer.

Fig. 21.



We now come, Fig. 21, to the marshalling of the figures that have been given in the previous curves. We take the State of Illinois, outside of Cook County and outside of a small suburban district in Lake County, and we find that on the lowest possible estimate the total light and power is 99,800 kilowatts on December 18th; the interurban and street railways used 81,500 kilowatts on a summer holiday, when their maximum comes. The town water-pumping takes 29,290 kilowatts and the ice-making 16,575 kilowatts; coal mining takes 38,530 kilowatts between 4 and 4.30 P.M. some day in November or early in December; the rural light and power takes 33,125 kilowatts in the summer; the drainage pumping 7125 kilowatts in the early spring; and we have a total of 305,945 kilowatts if you disregard altogether the time at which the maximum demand comes.

FIG. 22.



Now the generating plants, the transmission lines, and the sub-stations have to be designed and constructed to take care of the maximum demand made on you on one given day of the year, which is the day on which you get the highest demand from all those businesses put together.

I am trying to express myself in plain, everyday language for those who are not technical people, as there may be some amongst the audience.

With a separate generating and transmission system for each kind of supply, you have got to provide the investment necessary for that 305,000 kilowatts, so far as generation and primary distribution are concerned. What I mean by primary distribution is the transmission lines that go through the country to sub-stations, which transmission lines are operated at relatively high pressure, the pressure being reduced at the sub-stations where the energy enters the local distribution system.

Fig. 22 tells the story, graphically, of the saving effected. The town light and power load comes about 5.30 on December 18th. The demand of the interurban and street railways, which is 81,500 kilowatts in the middle of summer, is down to 78,460 on December 18th; the town water and pumping is down from 29,290 kilowatts in the middle of summer to 17,430 kilowatts on the day of your maximum load. Ice-making goes down from 16,575 in the middle of summer to 245 in the middle of winter; coal mining from 38,530 at the time of their maximum demand for energy to 4975 at the time of your maximum load in winter. The rural light and power load of 33,125 in the summer goes to 24,990 on the day of your maximum load. Drainage pumping load of 7125 kilowatts in early spring is entirely off at the time of your maximum load in winter, and the 305,945 kilowatts of total demand, irrespective of the time when that demand comes, is reduced to an instantaneous demand of 225,900 kilowatts, or a difference of 80,045 kilowatts, or, to express it technically, a diversity of 35.4 per cent.

There is one set of figures that we have left out of these estimates, and I refer to the amount of energy that would be required if the steam trunk-line roads of Illinois were electrified. I presume that when the time comes for electrification in the Central West it will follow somewhat the same course that is being followed in the East. The passenger terminals will probably be electrified first, because they seem to be the simplest to deal with; then will follow the freight terminals, and it will probably be quite a number of years before we get to a point where steam electrification will take place generally. It will probably take place east of the Alleghenies long before it takes place in the Mississippi Valley, because of the density of travel and movement of freight, and owing to density of population, which is so much greater east of the Alleghenies than it is in the Mississippi Valley; but when the time comes, as surely it must come, for the electrification of the great arteries of travel of the country, the economical way for the railroads to get their energy will be to get it from these plants that, in my judgment, will be spread, by that time, all over the States, with their transmission lines gridironing the various States and carrying cheap energy to the smallest possible community, thus changing entirely the basis of living, and giving less reason for great accumulations of population for manufacturing purposes in given centres because of the incentive of cheap power, which will not be confined to those centres, but will be available equally in small communities and in large communities. I very much doubt whether the conditions of load shown in the last two charts would be changed if all the steam railroads in Illinois were run electrically, except that the condition of diversity would probably be increased, and consequently the condition of operation would probably be improved and the cost of energy would be reduced, even beyond any figures I can show you to-night.

TABLE IV.

SUMMARY FOR YEAR.

	K. W. H.		Maximum K. W.				
	Amount	Per cent. of total	For year	5.30 P.M. Dec. 18	Diversity		Load factor
					Amount	Per cent.	
Light and power......	238,717,500	24.9	99,800	99,800	.....	..	27.3%
Interurban and street railway............	334,996,600	34.8	81,500	78,460	3,040	..	47.0
Water pumping.......	129,562,500	13.4	29,290	17,430	11,860	..	50.6
Ice-making...........	62,126,300	6.5	16,575	245	16,330	..	42.7
Coal mining..........	86,571,500	9.0	38,530	4,975	33,555	..	25.6
Drainage pumping....	7,250,000	0.8	7,125	....	7,125	..	11.6
Farming.............	101,562,500	10.6	33,125	24,990	8,135	..	35.0
Totals.........	960,786,900	100.0	305,945	225,900	80,045	35.4	35.9%

Load factor of combined systems 48.7%

Table IV sums up in figures what you have seen on the previous curves. It would seem to indicate—and I am rather inclined to think it is a low estimate—that the total amount of energy that could be disposed of at this time for the purpose of light and power, interurban street railways, water pumping, ice-making, coal mining, drainage, and general farm purposes in the State of Illinois, outside of Chicago, is about 960,000,000 kilowatt-hours, or about one-fifth greater than the present output of the city of Chicago. The maximum load would be 225,000 kilowatts combined, as against 305,000 with them separated, or slightly less than the Chicago maximum.

The last column shows you the load factor of all these businesses separately. The combined load factor of the entire system is 48.7, which is better than is obtained, so far as I am aware, in any large centre of population in the world, and with an amount of output which, as I have stated, exceeds by one-fifth the largest output, so far as I am aware, in any large centre of population in the world.

TABLE V.

Large Reserve Capacity.

In Local Plants.

	North-eastern Illinois	North-western Illinois	Central Illinois	Total
Number of towns for which information is available	6	16	47	69
Population	6,885	34,459	141,376	182,720
Maximum	415	1,897	5,898	8,210
Capacity	475	3,385	10,779	14,639
Per cent. reserve	14.5	78.5	82.9	78.4

Table V shows the reserve capacities, etc. I have had these figures prepared to show you the enormous reserve that small plants, as a rule, carry in Illinois. In northwestern Illinois they have 78.5 per cent. reserve; in central Illinois they have 82.9 per cent. reserve, or with 69 towns and 182,000 population and a maximum demand of 8210 kilowatts they have a capacity of 14,600 kilowatts, being a reserve of 78 per cent.; and yet the service under these circumstances is, as most of you know, very unreliable in small towns.

Table VI shows the estimated saving in plant investment. I have had this statement prepared, which I will refer to in a moment, giving a comparison of the generating plant cost for separate plants and for unified systems. The saving shown cannot be made except for new or additional business, and as the old plants are displaced on account of wearing out. However, with the rapid growth of all these classes of business, this investment saving can be made in a few years, in addition to an enormous operating saving.

We are assuming that these plants with an estimated capacity of 437,530 kilowatts are put in as separate plants, costing $43,753,000.

TABLE VI.

ESTIMATED SAVING IN PLANT INVESTMENT.

	Maximum K.W. as separate systems	Estimated percentage reserve	Estimated capacity
Light and power	99,800	50%	149,700 K.W.
Interurban and street railway	81,500	40	114,100
Water pumping	29,290	50	43,940
Ice-making	16,575	30	21,550
Coal mining	38,530	50	57,800
Drainage pumping	7,125	50	10,690
Farming	35,125	20	39,750
Totals	305,945	43%	437,530 K.W.

Estimated capacity 437,530 kilowatts at $100 per kilowatt	$43,753,000
Maximum kilowatts for above as combined system	225,900 K.W.
Plus 20 per cent. reserve capacity	45,180
Total estimated capacity for combined system	271,080 K.W.
Estimated capacity 271,080 kilowatts at $75 per kilowatt	$20,331,000
Estimated saving	$23,422,000

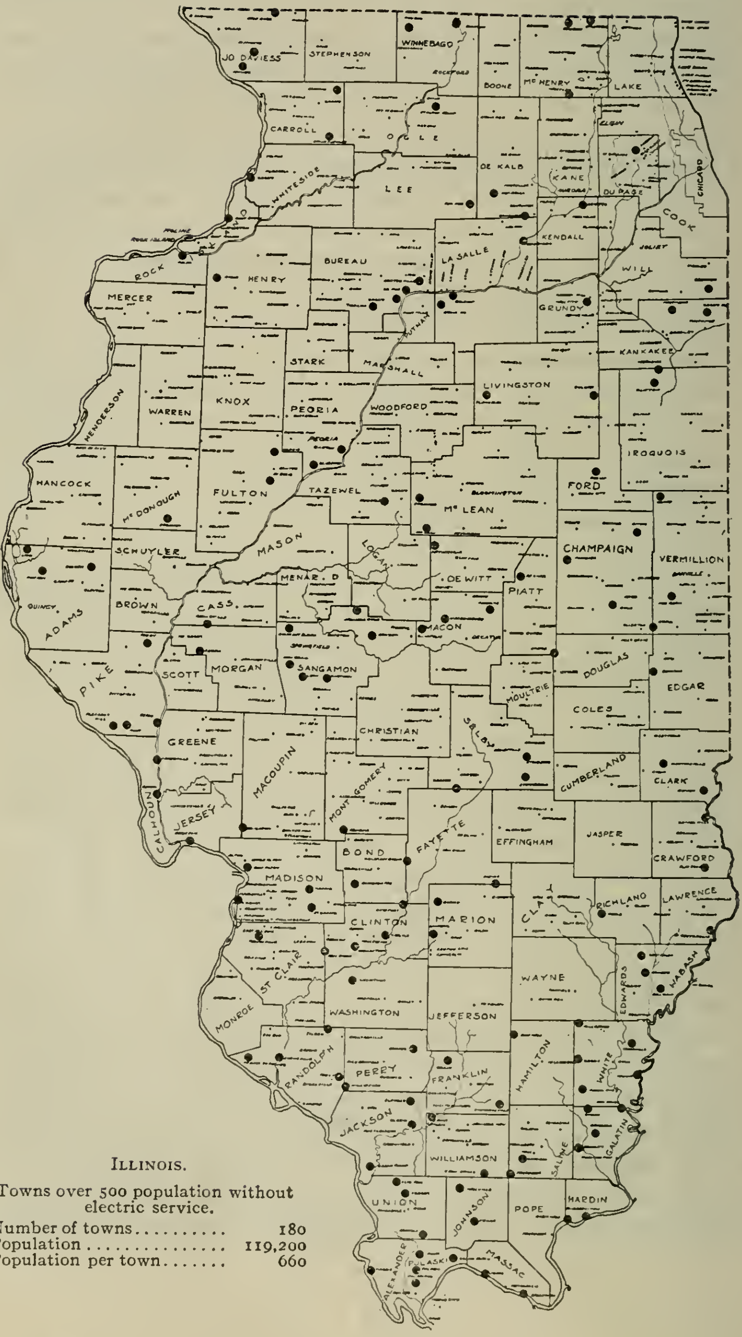
The maximum kilowatts for the combined system would be 225,900; with 20 per cent. reserve capacity, which is ample, the total capacity is 271,080 kilowatts, which at $75 per kilowatt is $20,331,000, showing an estimated saving of $23,422,000.

These figures are somewhat misleading to begin with. You could not handle that amount of business in the State of Illinois in small plants at $100 per kilowatt. The operating expenses of those small plants would be so great that it would be impossible to quote a price that would enable you to get the business, so that in a way you would say that would be an impossibility; it would be impossible to raise the money because you would be quite unable to make a showing with a series of separate plants. I do not know how many plants there would be, but they would run up into the hundreds. The only way to give cheap energy to a large rural community, whether it be to the manufacturing interests in those communities or for the necessities of the people, such as ice-making, or for mining of coal, or for the performance of public functions, such as water supply, the only possible way that it can be carried out is by concentrated production, which would call for the investment of $20,331,000 in stations.

To go into the matter of operating saving from that class of combination is almost beside the question, as that business can only be secured by a unified system of production having low investment cost in proportion to the load factor, and low operating cost in proportion to the load factor. To try to compare that with the costs of a lot of little local plants, worthless in themselves except for supplying a few lines in their own various communities, would not be of any particular advantage to us in looking into this subject, because the figures I would have to show would be, in a way, misleading, as I would have to assume that it would be possible to get the class and amount of business with the operation of small isolated plants that can only be obtained by a unified system of production.

The figures I have presented you show absolutely that the business in which I am engaged can be run only as a monopoly—successfully run, I should say, as a monopoly. To use the taxpayers' money in putting in a small lighting plant—in using the word "small" I speak relatively, meaning "small" as applied to towns with a population of 500 to 1000, and small as applied to a city of possibly one million or two million population, for what is small in one place would be relatively large in another place; but they are all equally small in total business obtained in any given centre of population—to put the taxpayers' money into that class of investment, whether it is in a little Illinois village or a large city in New Jersey or New York, is simply a waste of money, and, while I do not wish to enter into a discussion of any controversial character in an assemblage of this kind, I do not know of any greater argument against the municipalization of the production of energy than the study of the economics of the business in which I am engaged. A study of such figures as those I have thrown on the screen must lead any man of ordinary intelligence, not necessarily with technical experience, but any man with ordinary intelligence, to the conclusion that the only possible way to operate the business of energy production

FIG. 23.



ILLINOIS.

Towns over 500 population without electric service.

Number of towns..........	180
Population..............	119,200
Population per town.......	660

and distribution is by operating it as a monopoly in so much of the territory as you may want to serve from one organization. It does not necessarily follow that that organization shall cover the whole of a state or the whole of a county, provided the county is large enough for more than one. It does follow, however, that so far as any particular piece of territory is concerned, whether the energy produced be used for operating urban transportation, such as the surface lines and the underground lines, and the elevated lines in a city like Philadelphia, or a portion of the terminal lines, or the main lines of the steam railroads centering in Philadelphia, or the lighting of your streets or for supplying the thousand-and-one purposes that a community like this requires it for, such production and distribution of energy must, for reasons of economy, be a centralized one, whether such centralization be confined to the city or the county, or possibly covering a large portion of the state.

I have a few more slides which I think will interest you.

Fig. 23 is a map of Illinois showing towns of over 500 population which are without electric service, and in addition there is the rural district that is not served at all.

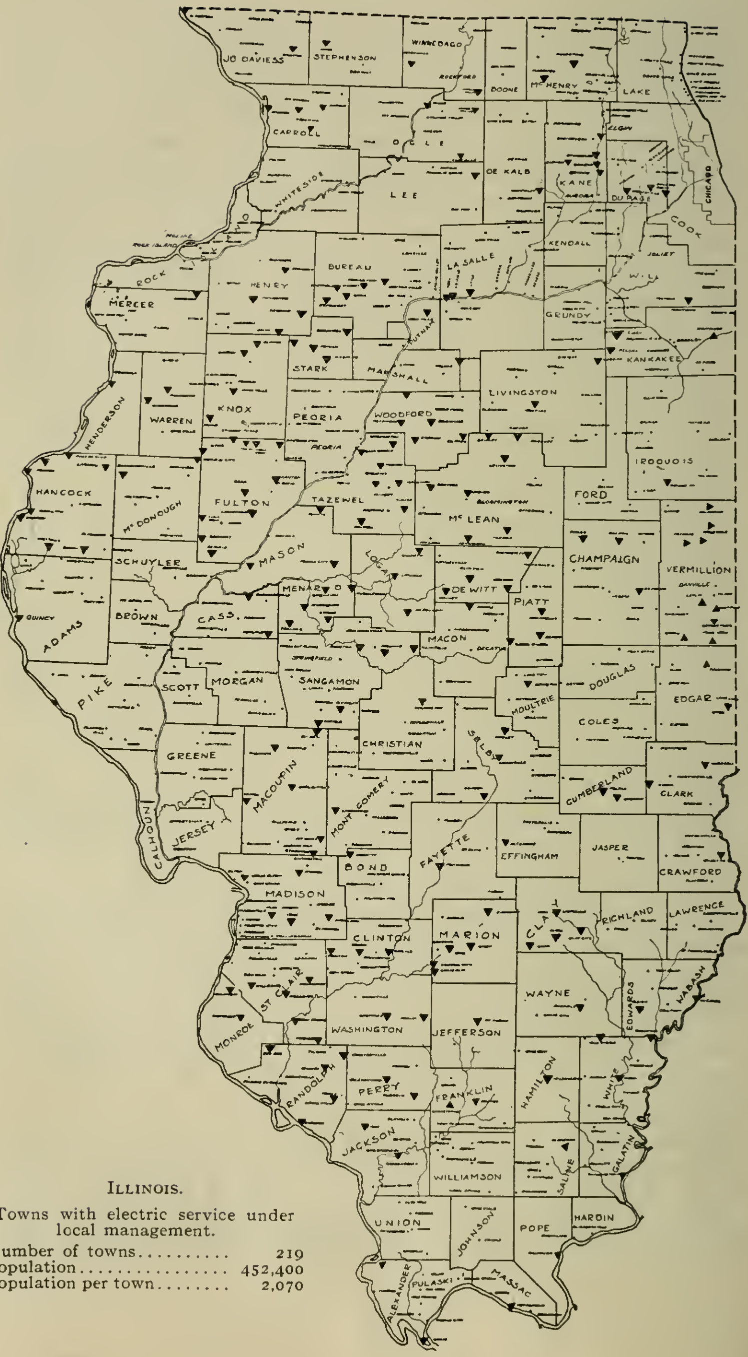
Fig. 24 is a map of Illinois showing all of the towns which have service from local plants owned and operated by local companies, and which, in a majority of cases, is only a six- or ten-hour service. There are 219 of these towns, of which 19 have a population of less than 500.

Fig. 25 is a map of Illinois showing all the towns in which the electric service is owned and operated by some group utility, which service is being rapidly interconnected with and operated from the most economical available source of supply.

Fig. 26 shows graphically the present electric service of the state of Illinois, exclusive of Cook County, analyzed according to population, showing that portion which has no electric service, that portion which has service from local plants, and that portion of the population which has service from some utility group. It brings out the fact that a little over half of this population is still without service.

Before taking my seat I want to say it would have been impossible for me to prepare any such statistics and curve sheets as I have shown you if I had not had at my command the devoted service of a large staff of statisticians, ably headed by Mr.

FIG. 24.



ILLINOIS.

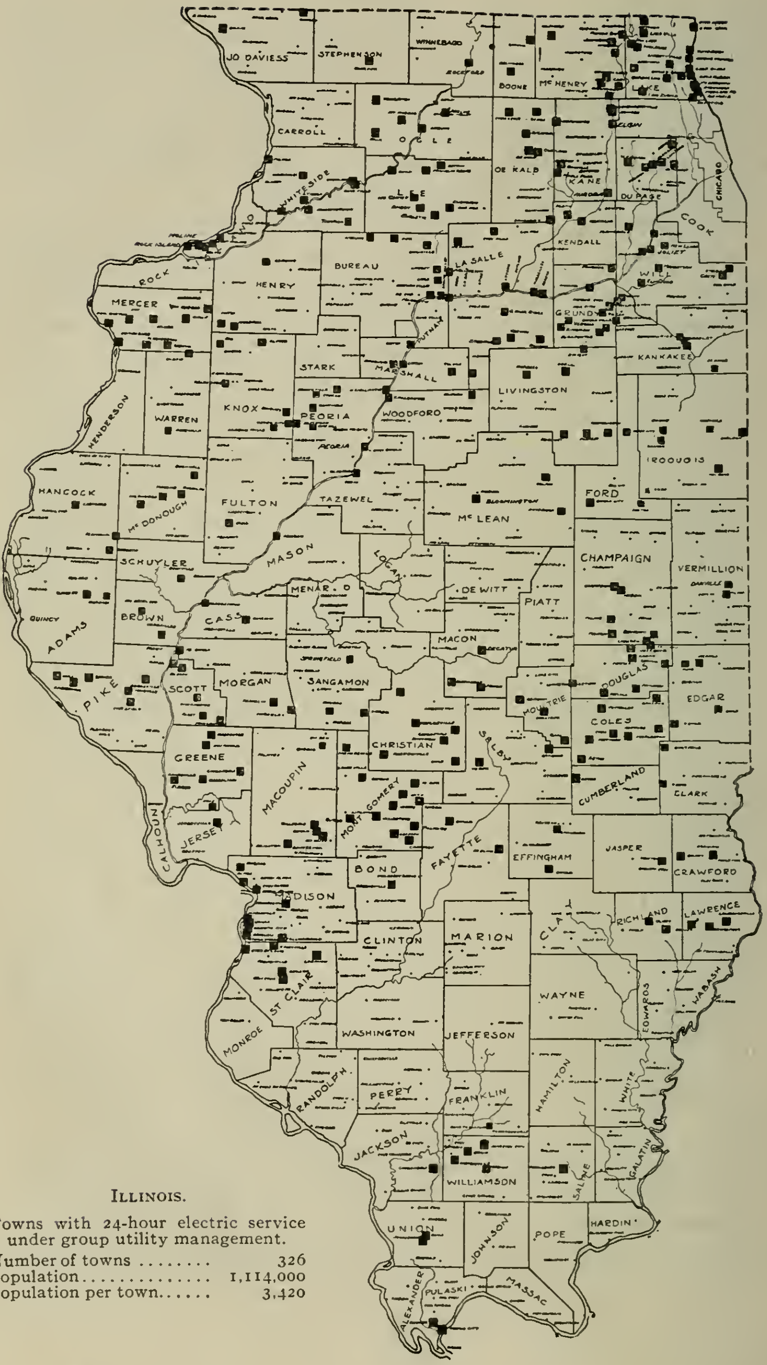
Towns with electric service under local management.

Number of towns..........	219
Population................	452,400
Population per town........	2,070

Edwin J. Fowler, Chief Statistician of the Commonwealth Edison Company, and Mr. George E. McKana, Assistant Chief Statistician, and I think it is only fair that I should, in this public way, refer to the great service they have rendered me, and also the service rendered by the officers of the various companies which it is my privilege to operate, in the preparation of the data that I am using before you this evening.

But you people in this part of the world are a good deal more interested in Pennsylvania,—that is, on this side of the Alleghenies,—than you are in Illinois, which is some distance the other side. The figures I have given you are not merely theoretical figures; they are figures that have been prepared in connection with the operation of businesses employing a very large amount of capital, which businesses have been organized for exactly the purposes which we have set forth as hoping to accomplish in the diagrams shown this evening. We believe that every corner of this country where density of population justifies it must have in the next few years a general central station supply of electrical energy for the general use of the people living in the small towns and the farming districts of the country. When I speak of density of population being a primary necessity, I probably exclude most of the territory lying west of, say, the centre of the Mississippi Valley until you get across the Sierra Nevada Mountains and reach the wonderfully productive territory of the Pacific Coast, extending practically from the Arctic Circle to the borders of Mexico. In the territory east of the centre of the Mississippi Valley it is not only possible but it is practically certain that we shall see in the next few years an opportunity to get cheap electric energy alike in the country community and in the large city. Just see what that means for a state like Pennsylvania. You have the advantage of low cost of production from the large steam generating plants of the two great cities of Philadelphia and Pittsburgh at practically opposite ends of this great state; you have a density of population of 171 per square mile, as compared with 101 in Illinois. If you eliminate cities of over 100,000 population, you have a density of 122 per square mile, as against 62 in Illinois. Or take your neighbor state, New Jersey, which has a density of population more than three times as great as that of Illinois, and if you will leave out the cities of over 100,000 population it

FIG. 25.



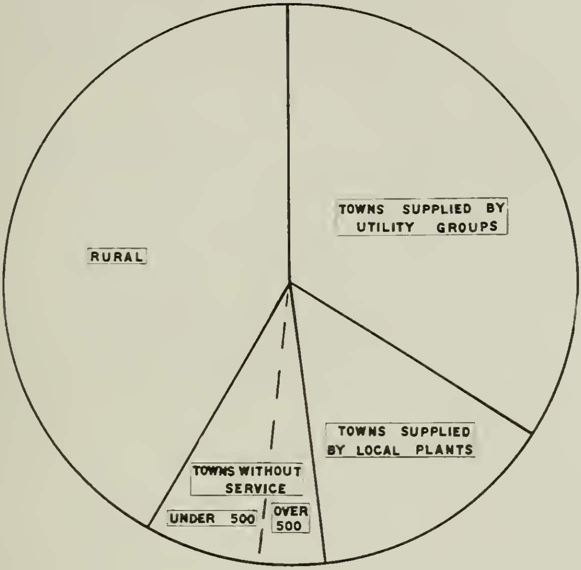
ILLINOIS.

Towns with 24-hour electric service under group utility management.

Number of towns	326
Population..............	1,114,000
Population per town......	3,420

has a density of almost four times that of the state of Illinois. So that what is possible for us on the other side of the Alleghenies is certainly equally possible for you people on the Atlantic seaboard. To come back to Pennsylvania, besides having the advantage of economical production at two ends of the state in very large centres of population, you have probably a million horsepower in water-power in the state; you have untold wealth in mines, and I cannot see why it should not be cheaper to transport energy the short distance that it would have to be transported to some of the large centres of population in Pennsylvania than to spend the money in transporting coal on the railroad. If it is possible to achieve anything like the cheap production of energy that a general unified system would have to do in the country districts, as comparable with the prices

Fig. 26.



Electric service analysis by population. Illinois, exclusive of Cook County.

	Towns.	Population.	Per cent. of total.
Supplied by utility groups	326	1,114,000	34.2
Supplied by local plants	219	452,400	13.8
Without over 500	180	119,200	3.6
Without under 500	1,713	216,300	6.5
Rural	...	1,366,100	41.8
Total	2,438	3,268,000	100.0

paid for energy in large centres of population, see what a difference it would mean to our working population. The manufacturer has to go where he can get cheap raw material, where he can call on a large labor market; still, there are many industries which can be developed in the centre of a farming district, where the farming population could be called upon to labor when they are not employed on the land. To my mind there is no more important factor in the great problems of life, the problem of how the workingman can get fresh air, the problem of how he can bring up his family in healthy localities, than the proper solving of the problem of the economical generation and distribution of energy for country districts.

I think it was Lord Macaulay who made the honest statement that "of all inventions, the alphabet and the printing-press alone excepted, those inventions which abridge distance have done most for civilization." Lord Macaulay died before the opening of the electrical energy era. I think if he were living to-day, and if he were penning those lines over again, he would have had in mind amongst the inventions which have abridged distance not only the telegraph and telephone, but he would add inventions that have enabled us to carry energy for the use of men at remote distances, in small towns and country districts.

Microstructure of German Silver. O. F. HUDSON. (*Inst. of Metals,* March, 1913.)—Samples of German silver, containing copper 58.0, nickel 18.5, and zinc 23.5 per cent., annealed under ordinary works conditions for varying lengths of time at 700° C., were polished and etched for micro-examination. A strongly acid solution of ferric chloride was used for etching. The usual crystalline growth on annealing was shown to take place, and the cold-rolled alloy still showed the original cored structure of the cast material, even after 48 hours' annealing at 700° C. After 72 hours' annealing at 700° C. the alloy was practically homogeneous. These observations were confirmed on material prepared in the laboratory and similarly treated. A coarse crystalline structure due to prolonged annealing showed in itself no sign of inferior rolling qualities, all the annealed specimens rolling easily and well. When tested for hardness by the Shore scleroscope no decrease in hardness was observed beyond that due to the normal annealing operation. The paper is illustrated by twelve micro-photographs.

STRESS CONSIDERATIONS IN AËROPLANE DESIGN.*

BY

DR. A. F. ZAHM.

THE United States Navy has initiated the expedient of requiring the prospective fabricator of its aëroplanes to furnish exact estimates showing their adaptation to the purposes and flight conditions specified by the officer in charge of aviation. This requirement serves a two-fold purpose: it stimulates more careful, more adequate design; it discovers and favors those firms capable of producing the best machines. Incidentally it tends to eliminate the incompetent manufacturer from the list of competitors for a most desirable patronage.

The data needed by so careful a purchaser as the Navy are manifold and searching. Besides the general dimensions and capabilities of its prospective flying-machines, it must have their fundamental details. It needs to know the strength and resilience of all the important parts of an aëroplane; the pressure distribution on them at all speeds and attitudes of flight, in both straight and curvilinear movement; the stresses in all parts under various conditions; the position of the centre of gravity, the travel of the centre of pressure, the moment of inertia referred to the axes of the machine; the character of its appliances for controlling the speed, poise, and steadiness of flight; the efficiency of the engine, of the propulsive system, and of the aëroplane as a whole; the possible range of speeds; the running expense; the qualifications for launching and lighting on land and sea.

Some part of this information can be obtained directly by calculation from the general dimensions of the aëroplane; but a large portion can be acquired only through experimentation. We may in this article consider some of the questions which can be answered directly by simple analysis.

As an example, suppose that the speed and curvature of path are given for a specified aëroplane in uniform horizontal flight, and that the manufacturer is required to furnish stress diagrams of the main wing-framing for these conditions. He may assume that the machine is banking around a level curve and held to its course, as shown in Fig. 1, by three forces: the weight *W*, the centrifugal force *F*, and the wing pressure *P*, which just balances the other two, and can be represented as the diagonal of a rectangle constructed on them as sides. If now he can find the relation of this wing pressure to the weight of the aëroplane, for the given conditions, he may proceed to work out the required stress diagram. But from the force rectangle just mentioned it is obvious that the ratio of *P* to *W* is the secant of the angle of the bank, while the tangent of that angle is the ratio of *F* to *W*. This latter ratio has the familiar value V^2/gR, in which *V* is the speed of flight and *R* is the radius of curvature of the horizontal path.

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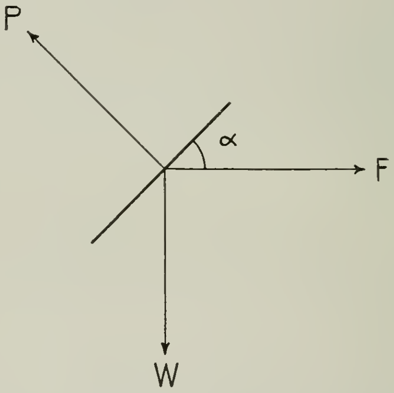
* Communicated by the author.

FIG. 1.



Forces acting upon aëroplane in curvilinear flight.

For the convenience of busy engineers, and for illustrating the stress resulting from speed and curvature of path, we may here produce a table of values of the total pressure perpendicular to the wings, after first deriving the centrifugal force and angle of steady bank for various speeds and curvatures of path. The table will be the more interesting because directly applicable to any car rounding a banked track in running equilibrium,—that is, without tendency to skid to right or left. Taking *V* as miles an hour, *R* as feet, and *g* for simplicity as 22 miles an hour, or 32.1 feet per second, the above expression for the tangent of the angle of bank assumes the easy numerical value $V^2/15R$. By means of this the tangent may be computed for various speeds and curvatures of path; then by use of trigonometric tables the angle of bank and the secant may be read off. In this manner was formed the following table in which a is the angle of bank; F/W is its tangent; P/W is its secant. The centrifugal force and whole force perpendicular to the wing surface are thus given in percentage of the gross weight of the aëroplane. The table is accurate to the third decimal place, and covers all speeds and curvatures important in the present practice of aëronautical engineering. Obviously the values of F obtain as well also for flight in an oblique or a vertical plane; and, in particular, at the bottom of a swoop the whole normal force P equals F plus the gross weight of the aëroplane; that is, it is found by adding unity to the values given in the columns headed F.

The limiting values in the table, though extreme, are not without interest. They show, for example, that at a speed of twenty miles an hour, or about that of various soaring birds, the normal stress in the wings due to sharp horizontal circling is increased very little,—in fact, only three and one-half per cent. for a radius of curvature of 100 feet. At high speeds, however, such sharp wheeling is unbearable by either the aviator or the machine, if the latter be of ordinarily good construction. Thus at two miles per minute the wind force perpendicular to the wings is multiplied nearly tenfold by rounding a curve of 100-foot radius, and more than doubled on a curve of 500-foot radius. But what happens when an aviator plunges vertically earthward from an altitude of one mile, and acquires a speed alleged to equal 200 miles an hour? For this case the table shows that, if the aëroplane is gradually levelled out, on a curve of 1000-foot radius, the centrifugal force is 2⅔ times the gross weight of the machine, and hence that the whole force on the wings is 3⅔ times its gross weight. An aviator weighing 150 pounds would, therefore, press on his seat with a force of 850 pounds. Even so, he would have to begin straightening his machine at an elevation of one thousand feet in order to strike the earth tangentially. Should he begin levelling at a much less altitude, he would suffer sure disaster: for if he curved his path too little he would strike the earth at a considerable angle and at terrific speed, while if he curved enough to avoid this shock he would place an excessive burden upon the framing of his aëroplane and upon his own skeleton.

This last example may be generalized. We may suppose

TABLE I.

Values of the Natural Angle of Bank α Degrees, Centrifugal Force F, and Whole Force P, Perpendicular to the Wings, for an Aëroplane in Steady Circular Flight Round a Level Curve of Radius R, Feet. F, and P; Expressed in Percentage of the Whole Weight W.

Flight Speed	R = 100 Feet			R = 200 Feet			R = 300 Feet			R = 400 Feet			R = 500 Feet			R = 600 Feet			R = 800 Feet			R = 1000 Feet		
Miles per hour	α	F	P	α	F	P	α	F	P	α	F	P	α	F	P	α	F	P	α	F	P	α	F	P
20	14-56	0.267	1.035	7-36	0.133	1.009	5-5	0.089	1.004	3.49	0.067	1.002	3-9	0.053	1.002	2-33	0.044	1.001	1-55	0.033	1.001	1-32	0.027	1.000
30	30-58	0.600	1.166	16-42	0.300	1.044	11-19	0.200	1.020	8-32	0.150	1.011	6-51	0.120	1.007	5-43	0.100	1.005	4-18	0.075	1.003	3-26	0.060	1.002
40	46-51	1.067	1.462	28-4	0.533	1.133	19-34	0.356	1.061	14-56	0.267	1.035	12-3	0.213	1.022	10-5	0.178	1.016	7-36	0.133	1.009	6-5	0.107	1.006
50	59-2	1.667	1.944	39-48	0.833	1.302	29-3	0.556	1.144	22-37	0.417	1.083	18-26	0.333	1.054	15-31	0.278	1.038	11-46	0.208	1.021	9-28	0.167	1.014
60	67-23	2.400	2.600	50-12	1.200	1.562	38-40	0.800	1.281	30-58	0.600	1.166	25-38	0.480	1.109	21-48	0.400	1.077	16-42	0.300	1.044	13-29	0.240	1.028
70	72-59	3.267	3.416	58-31	1.633	1.915	47-26	1.089	1.478	39-14	0.817	1.291	33-9	0.653	1.195	28-34	0.544	1.139	22-13	0.408	1.080	18-5	0.327	1.052
80	76-49	4.267	4.383	64-53	2.133	2.356	54-53	1.422	1.739	46-51	1.067	1.462	40-29	0.853	1.315	35-25	0.711	1.227	28-4	0.533	1.133	23-6	0.427	1.027
90	79-31	5.400	5.492	69-41	2.700	2.879	60-57	1.800	2.059	63-28	1.350	1.680	47-12	1.080	1.472	41-59	0.900	1.345	34-1	0.675	1.206	28-22	0.540	1.136
100	81-28	6.667	6.741	73-18	3.333	3.480	65-46	2.222	2.437	59-2	1.667	1.944	53-8	1.333	1.667	48-1	1.111	1.495	39-48	0-833	1.302	33-41	0.667	1.202
110	82-56	8.067	8.128	76-5	4.033	4.155	69-36	2.689	2.869	63-37	2.017	2.251	58-12	1.613	1.898	53-21	1.344	1.675	45-14	1.008	1.420	38-53	0.807	1.285
120	84-3	9.600	9.652	78-14	4.800	4.903	72-39	3.200	3.353	67-23	2.400	2.600	62-29	1.920	2.165	58-0	1.600	1.887	50-12	1.200	1.562	43-50	0.960	1.386
130	84-56	11.27	11.31	79-56	5.633	5.721	75-5	3.755	3.886	70-27	2.817	2.989	66-4	2.253	2.465	61-58	1.878	2.127	54-37	1.408	1.727	48-25	1.127	1.506
140	85-37	13.07	13.10	81-18	6.533	6.609	77-4	4.356	4.469	72-59	3.267	3.416	69-4	2.613	2.798	65-20	2.178	2.396	58-31	1.633	1.915	52-34	1.307	1.645
150	86-11	15.00	15.03	82-24	7.500	7.566	78-41	5.000	5.099	75-4	3.750	3.881	71-34	3.000	3.162	68-12	2.500	2.693	61-56	1.875	2.125	56-19	1.500	1.803
175	87-12	20.42	20.44	84-24	10.21	10.26	81-38	6.806	6.879	78-55	5.104	5.201	76-14	4.083	4.204	73-37	3.403	3.546	68-36	2.552	2.741	63.54	2.042	2.273
200	87-51	26.67	26.69	85-43	13.33	13.37	83-35	8.889	8.945	81-28	6.667	6.741	79-23	5.333	5.426	77-19	4.444	4.556	73-18	3.33	3.480	69-27	2.667	2.848

the aëroplane, at a given altitude h, to be plunging at speed V, down a slope of ϑ degrees to the horizon, and inquire what centripetal force will compel it to descend in a vertical circle tangent to the earth. From elementary trigonometry one easily finds the radius of curvature of such a tangent circle to be $R = h/\text{versin}\ \vartheta$ and from a trigonometrical table one derives the following values of $1/\text{versin}\ \vartheta$ for the angles tabulated:

TABLE II.

Angle of dive	10°	20°	30°	40°	50°	60°	70°	80°	90°
$1/\text{versin}\ \vartheta$....	65.8	76.6	7.47	4.27	2.80	2.000	1.52	1.21	1.000

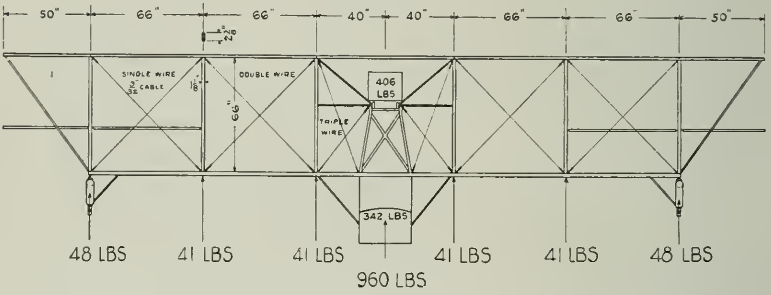
Having found from this table the radius of curvature, a glance at Table I will show the force on the wings. For example, if an aëroplane at an altitude of 100 feet dives at an angle of 50° and speed of 60 miles an hour, its easiest volplaning radius of curvature is, from Table II, 280 feet, and hence, from Table I, the centrifugal force F is .96 of the gross weight. This added to the weight itself shows that at the bottom of the swoop the whole force across the wings is nearly doubled. If the assumed altitude had been 50 feet instead of 100, the radius of the circular swoop would have been but half as great, and hence the centrifugal force would have been doubled and the whole force trebled. From these figures it is easy to understand that an aviator, in attempting to startle pedestrians by diving toward them, may suddenly find his easiest circle of recovery too small to follow safely, and himself, therefore, doomed either to strike the earth at a deadly angle of impact, or to overstress his machine in mid-air and to fall with its wreckage.

But these remarks on Table I are a digression. The table was prepared as preliminary to finding the stresses in the framing of an aëroplane in curvilinear flight. To simplify this latter task we may assume that when the whole wind force perpendicular to the wings is increased in any proportion the corresponding stresses in the parts of the frame are increased in like proportion. If then we know these stresses for level rectilinear flight, those for level curvilinear flight can be found by multiplying by the proportionate values shown in column P of Table I.

Our first concern, then, is to find the stresses for level rectilinear flight. This may be done either by analysis or by graphical construction. If, for example, the front elevation of the structure be as shown in Fig. 2, we may suppose the whole wind-lift, which equals the weight, to be uniformly distributed from end to end of the wings, or approximately so, and assume that the upward force exerted on each post equals half the sum of the wind-lifts on the adjacent panels of the sustaining surface, less half the weight of these adjacent panels and their trussing.

Consider, for example, the Curtiss naval hydro-aëroplane of 1912 (Fig. 2), in uniform level flight, and sustained by a wind-lift of five pounds per running inch from tip to tip of its wings. The external arrows in Fig. 3 show the wind-lift exerted upward on the posts, while the internal arrows, bearing values found by analytical statics, show the resulting stresses induced in the framing.[1] One-half of the stay wires are omitted from the sketch because, under the assumed conditions, these are not stressed unless the wind for an instant strikes the wings on their upper surface. In this case the shown wires would be unstressed and the omitted ones would be stressed very like the ones portrayed in the diagram. This does not indicate that the omitted wires are less severely tried; for when the aëroplane is suddenly arrested in landing they may be subject to instantaneous stresses no less intense than those which the shown wires experience in regular flight under full load.

Fig. 2.



Front view of Curtiss naval hydro-aëroplane of 1912.

The foregoing diagrams present the internal stresses computed by the method of analytical statics, as practised familiarly by bridge engineers. The graphical treatment of the same is given in the lower part of Fig. 3. Both methods, when fully carried out, show the stresses to be very light in the framing of the end panels, much severer in the next ones, and still more intense in the engine section, which is here untreated because of its complexity. When tested by measuring instruments these theoretical forces are found to agree well with the measured ones. As a consequence of this combined evidence and of the observed fact that his uniformly wired machine used to break its stays at the inner panels, Mr. Curtiss had adopted the practice of increasing the strength of his aëroplane trussing, step by step, from the wing tips inward to the engine section. Curiously enough, though this gradation of stresses in an aëroplane has been understood by trained engineers since the appearance of the earliest aërial gliders, it has not, even up to the present writing, received due recognition from the generality of aëronautical designers.

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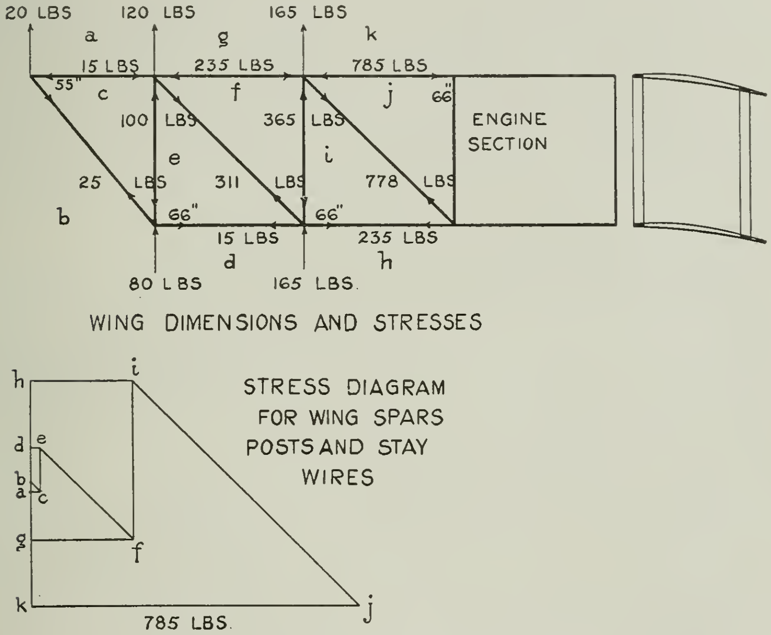
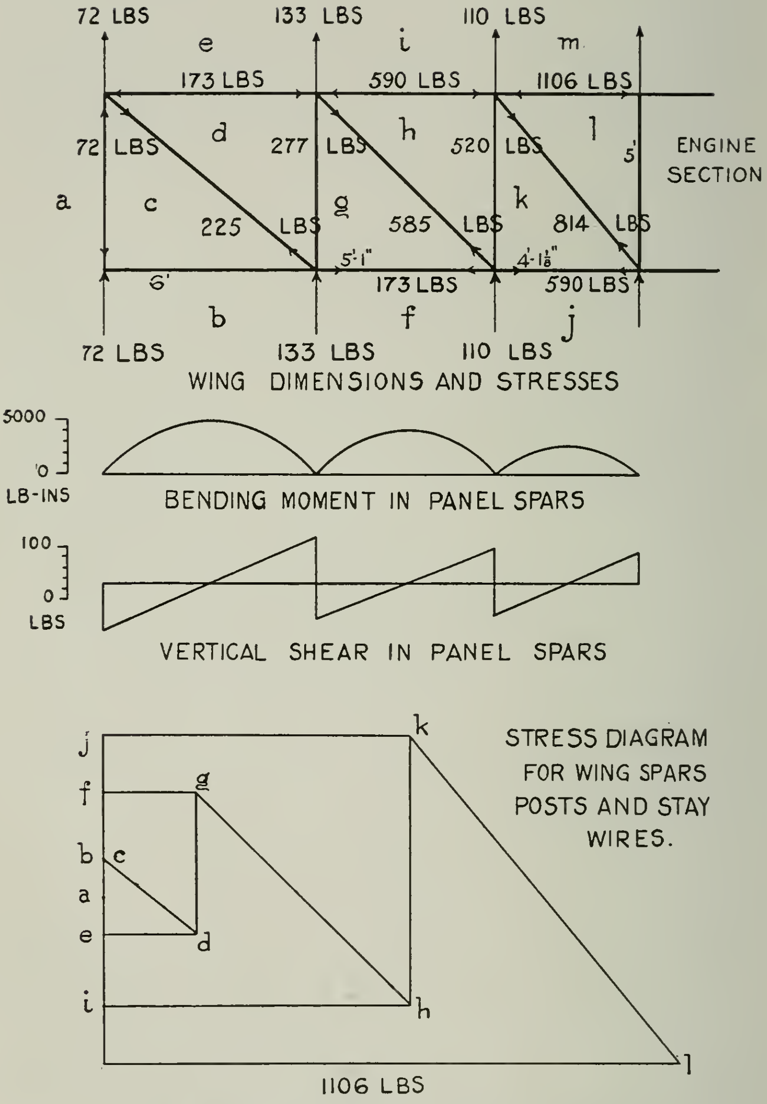
[1] Each of the stresses shown must be divided between the front and rear members, whether wires, posts or spars, probably in nearly equal ratio front and rear.

FIG. 3.



Analytic and graphic analysis of stresses due to wind-lift in Curtiss naval hydro-aëroplane, 1912.

Fig. 4.



Analytic and graphic analysis of stresses due to wind-lift in Wright biplane, Model C, 1912.

Figs. 5 and 6 show a like treatment of the forces in a Wright biplane, of model C, for 1912, sustained by a wind-lift of four pounds per running inch. The diagram gives the magnitude of the panels and of the applied forces, assuming the running lift and weight to be practically constant from wing tip to engine section. It also gives the stresses in the framing, assuming the third panel from either end to have but one stay wire—the upper one—in operation. When both the upper and lower wires in the third panels are strained together, their stresses can be computed by a slightly more complicated method involving the theory of elasticity. But by assuming each of the two wires in such panel to operate alone, while its mate is slack or injured. we obtain the major limit of its possible stress in regular flight. The stress in the under wire is about 1.5 times that in the wire above it.

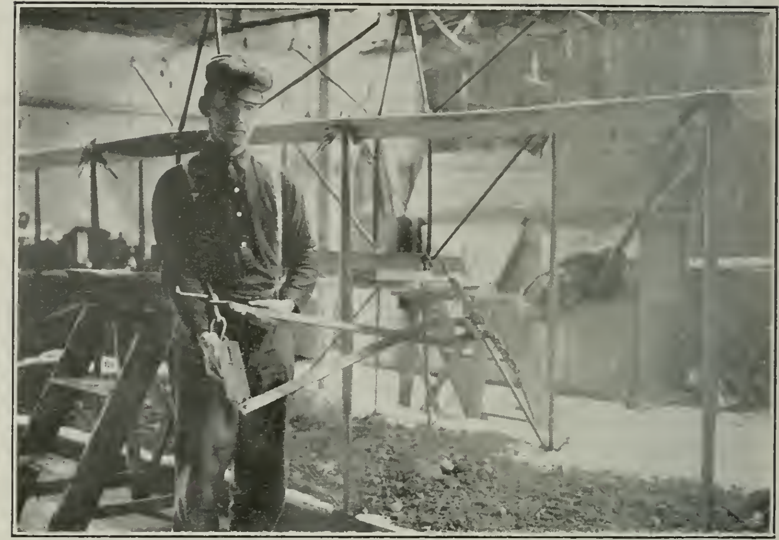
In this aëroplane, as in the Curtiss machine, the stresses are seen to increase rapidly from either wing tip to the engine section. But the design does not show a proportionate increase of strength in the stays and woodwork. If, therefore, the framing of this Wright machine be strong enough at the inner panels it must be overstrong at the outer ones. For want of sufficient data the stresses have not been found for the engine section, nor has account been taken of the stresses due to impact against the earth.

We have now found the frame stresses due to wind-lift for two aëroplanes of well-known types. The method can easily be extended to all other types. To avoid minutiæ, the effect of the individual weight of each post and panel surface has been disregarded; but, since these weights run nearly constant from wing tip to engine section, their effect is merely to diminish in the same proportion all the stresses due to wind-lift. This uniform reduction should be made in more exact estimates.

The stresses due to wind-drift and head resistance can be analyzed in a similar manner. Such analysis discloses a considerable additional tensile stress in the front spars and compressive stress in the rear spars. Combining these with the stresses due to wind-lift previously treated, we find the greatest tensile stress to be in the lower front spar, and the greatest compressive stress in the upper rear spar.

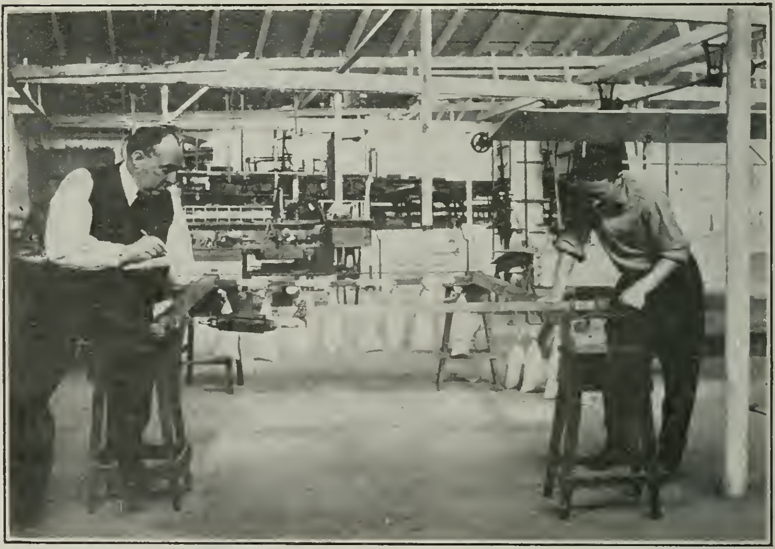
At the suggestion of the writer, Mr. Curtiss has determined

FIG. 5.



Tension tongs applied to measure stresses in aëroplane wires.

FIG. 6.



Apparatus for measuring longitudinal and transverse stresses on aëroplane spar, and deflection caused by them.

experimentally these complex stresses and the strains produced by them. He laid an aëroplane on its back upon a trestle, so placed as to support the middle of its engine section, then loaded its wings with gravel in such manner as to stress their framing approximately as in natural flight. By means of a pair of specially designed tension tongs he now measured the actual stress in each stay wire, and found it to be of the same order of magnitude as that determined for it by analytic and graphic methods.

The tension tongs and the manner of using them are exhibited in Fig. 5. They are like a blacksmith's tongs with jaws slit at their tips to receive and grip the wire at two points an inch or more apart. A spring balance attached to the tips of the tongs handles is made to draw them together far enough just perceptibly to slacken the wire. The tension of the spring is then read and multiplied by the ratio of the length of the handles to that of the jaws. The product is the tension in the stay wire.

The end stress in the posts and spars, though not directly measured by this instrument, is so simply related to the measured stresses as to be estimated directly and with precision. But a more serious question about the spars is the effect of the transverse wind force combined with the endwise thrust, or tension. This effect can be computed by the well-known methods of the theory of elasticity, and has been experimentally tested, in the Curtiss aëroplane factory, by means of improvised apparatus suggested by the writer. A rough analytical estimate may be made here.

To determine analytically the substantial deformation of a spar due to the external forces acting thereon, the spar may be treated as a simple beam uniformly loaded and subjected at the same time to end thrust. Omitting, for the present, the end thrust, the deflection f, at the middle of the panel spar, is given by the formula of applied mechanics, $f = wl^4/77\ EI$, in which w is the running load, l the length of the beam, E the modulus of elasticity of its material, I the moment of inertia of its cross-section. For the Curtiss machine here considered, $w = 5/4$ pound for a single spar, $l = 66$ inches, $E = 15{,}000{,}000$, say, $I = 1/12\ bd^3 = 1/12.\ 1\tfrac{3}{4}\ (3/2)^3$, in which b is the width of the spar, and d its depth. The formula for the deflection of the spar at the middle, therefore, gives $f = 0.31$ inch, due to the transverse wind pressure in level rectilinear flight. This bending would not, in the end panels, be materially increased by the lengthwise thrust in the spars; but in the engine section and the adjoining panels the additional deformation due to end thrust may be worth noticing. In normal flight the end thrust is shown by the analytic diagram to be $785/2$ pounds in one spar of the second panel, and, multiplied by 0.31 inch, gives 122 pound-inches as its bending moment, roughly estimated; while the bending moment at the middle, due to the uniform wind-lift on that spar, is about $1/8. wl^2 = 1/8.5/4.66^2 = 681$ pound-inches. If the wind-lift be doubled, as by sharp curving, the bending moment and consequent deflection are doubled; and, since the end thrust is also doubled, its bending moment and the consequent deflection are quadrupled: the first moment is therefore approximately 1362, the second roughly 488; the first causes a deflection of 0.62 inch, the second an additional deflection of slightly over 0.2 inch. A like deflection may be found for the Wright biplane and others.

The greatest horizontal unit stress S, in the fibre of the spar in question, due to the wind-lift, may be computed by use of the formula for a uniformly loaded simple beam, $S = Mc/I$, in which M is the bending moment, c the distance from the "neutral" surface to the outer fibre of the spar—being, in the present case, the distance from the centre of the cross-section to the upper or lower part thereof, and equal to ¾ inch. Now, assuming $M = 681$, and I as above, the value of S is found from the formula to be $681.\frac{3}{4}.1/12.1\frac{3}{4}.(3/2)^3 = 1023$ pounds per square inch, as the unit stress due to that value of M. The moment 122 exerted by the end thrust on the bowed spar induces a further unit stress roughly equal to $122/681 \times 1023$, which, added to the above, makes approximately 1200 pounds per square inch as the stress in the outer fibre due to the whole bending moment here considered. To this must be added the uniform compressive unit stress all over the cross-section of the spar, which is found by dividing the whole end thrust by the area of the section. This equals $785/2 \div 1\frac{3}{4} \times 1\frac{1}{2} = 150$ pounds per square inch: and, added to the above 1200, makes practically 1350 pounds per square inch as the unit stress in the outer fibre. This must be somewhat increased in case of the upper rear spar to include the effect of the drift on the wings in generating end thrusts in the rear spars. Possibly 50 pounds per square inch would be added from this source, if we assume the drift to be about one-eighth of the lift. Thus in level rectilinear flight in still air the unit stress in the upper rear spar of the second panel may equal 1400 pounds per square inch. As this must be greatly increased for the stress in circular flight, in swooping and in passing over "humps" in the air, it appears that the spar ought to be thickened at this part of the wing in order to increase the factor of safety.[2] In passing, it may be noted that $S = Mc/I \propto 1/d^2$, since $c = d/2$, and $I \propto d^3$. Hence, if the spar be doubled in thickness, the stress S is but one-fourth as great.

The experimental method, before referred to, for determining the combined effect of the end thrust and transverse wind force, is shown in the adjoining figure, 6. A horizontal portion of the spar 66 inches long is stressed endwise a chosen amount by the lever and spring-balance, and at the same time transversely loaded with sand bags. By gradually increasing these forces and observing the corresponding deflections, till the elastic limit is reached, the factor of safety for any intermediate stressing may be determined. It is desirable that the stresses in actual flight be measured for a considerable range of conditions.

The means available for determining the stresses in the parts of an aëroplane in actual flight are manifold. If the stay wires sing and by means of some device the pitch of each be observed, or recorded, the stress may be read from a suitable table, or computed from the physical specifications of the wire. The stresses in the adjoining posts and spars are derived at once with certainty by multiplying by a simple numerical factor obvious to every engineer. But, whether the wires sing or not, their tension can be directly measured by one of several methods, as by attaching their ends to a force-measuring lever, or spring, in such manner as not to alter the diagonal distance of the stay-wire terminals. Once having found the stresses in level uniform flight, they may be estimated for accelerated motion, more particularly transverse acceleration, by first recording these sudden changes of velocity by means of an accelerograph. If, for example, this instrument shows a transverse acceleration equal to one-half that of gravity at the place of flight, the corresponding increment of stress may be taken as one-half that observed in even flight, disregarding the effect of sudden strain.

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[2] This suggestion from analysis has been adopted in Mr. Curtiss's more recent military biplane, in which furthermore the spars are continuous from engine-section to wing tips.

The magnitude, direction and position of the wind force on each segment, or panel, of the aëroplane should likewise be determined in uniform level flight. This can be done by the manometric method of determining the pressure at each point of the surface and framing, then summing over the whole to find the resultant force. But a more direct method is to attach the panel, or segment, of the wing to the main part in such manner that it can slide freely up and down and fore and aft, and rotate about a vertical or longitudinal axis. No great difficulty should be experienced in attaching the segment so as to permit these three movements through a very slight distance. If now the forces opposing these three very small displacements be measured in actual flight the resultant wind force is completely determinate.[3] The equations applicable to these three statical conditions will be obvious to the trained engineer.

NOVEMBER, 1912.

Use of Thermit for Obtaining Sound Steel Ingots. H. GOLDSCHMIDT. (*Iron and Steel Inst. Journ.*, lxxxvi, 78.)—The method formerly adopted of pushing a thermit cartridge through the crust and into the pipe of a partially solidified ingot to melt the surrounding metal did not work satisfactorily. Latterly the cartridge has been pushed right down to the bottom of the ingot before solidification commenced. The vigorous reaction set up brings about an energetic agitation of the contents of the mould, expelling the liberated gases and driving the segregate upward. When the reaction has subsided, considerable subsidence of the metal occurs, and fresh metal is poured in from the ladle. The new method has proved very efficient, especially in the case of non-siliconized steel. A saving of 36 cents per ton is effected on the rolled material, which also shows greater uniformity in mechanical properties than untreated steel.

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[3] This assumes that the lift drift ratio is the same all over the wing segment; otherwise a fourth equation may be needed; and this may be formed by taking moments about two axes instead of one only.

RECENT PROGRESS IN THE STANDARDIZATION OF DISINFECTANTS.*

BY

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THE trend of medical science to-day is toward prevention rather than cure. The battle against those microscopic vegetable organisms which are the causative agents of disease is an increasing one. In this battle the true scientist uses, as one of his principal weapons, "*disinfectants*," or, to be more exact, "*bactericides*." The question as to the efficiency of these agents is one which cannot be solved by chemical analysis, but which requires methods, special in their field, to obtain a rational solution. It is the writer's intention to briefly give a *résumé* of the work which has been done in the past toward development of a standard bacteriological method for this purpose, as well as a general survey of the status of disinfectant standardization, both in this country and abroad.

The standardization of disinfectants as to their germicidal power is a matter of no little importance. At present there are many preparations on the market which are practically valueless, and whose use causes a menace of "fancied security" to the public. It is only just that the user of such an article knows exactly what its real efficiency is. This is the primal aim of disinfectant standardization—to protect the public from fraud, to give the layman an opportunity to exercise intelligent selection, to place upon the label of every article sold for germicidal purposes a plain, clear statement of its real value, instead of a multitude of fictitious claims and assertions, few of which could be substantiated by an impartial scientific inquiry.

The writer will pass over the various works published up to 1881. Before that time all experiments on the action of disinfectants had been qualitative. In the year mentioned, Koch[1] put forth the "*thread method*" of testing the relative activity of disinfectants. Threads impregnated with anthrax spores were submitted to the action of various dilutions of different disinfectants, thoroughly washed with sterile water to remove the residual disinfectant, and then planted on solid culture media. So far as the writer knows, this method is in no general use at present, having been supplanted by more improved procedures proposed later.

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* Communicated by the author.

This method was used by various workers for some years, of whom Esmarch,[2] Fraenkel,[3] Henle,[4] Behring,[5] and Geppert [6] may be mentioned. The next method set forward was by Krönig and Paul,[7] and is known as the "*garnet method*." In this, garnets of a uniform size were sterilized and dipped into a culture of anthrax spores and allowed to dry. These were then placed in the disinfectant, and at various intervals several were removed, gently washed to remove excess of disinfectant, and then placed in a definite amount of sterile water and shaken strongly enough to detach the adherent organisms. A measured quantity of this wash water was then plated in the usual way, and the colonies of bacteria which developed were counted. In the same year Defries [8] proposed a method which essentially consisted of placing a few drops of culture in a tube, allowing it to dry to a film, introducing the disinfectant, and, after the desired time had elapsed, pouring it out, washing, and adding sterile broth. Incubation then showed whether the bacteria had been killed. Neither of these methods is standard to-day, although the former has been quite extensively used by different workers,—Madsen and Nyman,[9] Firth and Macfayden,[10] etc.

The method that has enjoyed the greatest prominence and has come into most general use is the "*drop method*," as originally proposed by Rideal and Walker [11] in 1903.

The essential feature of this method is the comparison of the strength of disinfectants which kill *B. typhosus* in a definite time under carefully standardized conditions, with the strength of pure phenol solution necessary to accomplish the same results under the same conditions. Four dilutions of the disinfectant under test, and one dilution of phenol, are taken, and a definite amount of *B. typhosus* culture added to a definite amount of the various dilutions under sterile conditions. At various times, in regular order, sub-cultures are made, using a standardized loop, and the results observed after 48 hours' incubation. The quotient obtained by dividing the dilution of disinfectant which kills in a definite time by the dilution of phenol required to perform the same work in the same time is called the "Rideal-Walker coefficient" of the disinfectant. All the variables in the test have been carefully standardized, so that by *close attention to details* concordant results may be obtained by different workers.

This method was variously modified by the authors and others. Somerville and Walker [12], [13], [14] proposed the use of organic matter in the diluent in the test. Their experiments concerned the use of 1 per cent. solution of blood-serum, mucin, peptone, casein, gelatin, blood and starch, and various mixtures of these materials. Chick and Martin [15] suggested the addition of powdered feces in the test. Fowler [16] proposed the use of urine in this work. Blyth [17] used milk as added organic matter in the determination. All these suggestions were reviewed in great detail by Rideal and Orchard.[18]

The addition of organic matter was approved by them, but the kind and amount should be clearly stated in reporting the test. The organic matter used would naturally depend on the use to which the disinfectant was to be put, as suggested by Somerville and Walker.

In 1909 the Lancet Commission [19] proposed several changes in the Rideal-Walker test. *B. coli* was used instead of *B. typhosus,* and MacConkey's bile-salt medium replaced beef broth. The time interval was lengthened, and spoons replaced the loops used for inoculation. For some years the literature of disinfectants was very much filled with controversy regarding the merits of the two methods. The final result was that the original Rideal-Walker method prevailed, and became the standard in England, while the method of the Lancet Commission fell into disuse.

Quite recently a similar controversy has been opened up again in this country. Anderson and McClintic [20] propose what they style the "*Hygienic Laboratory Method,*" to replace the Rideal-Walker method. The principal changes involved are the increase in the number of dilutions of both phenol and disinfectant, the change in strength of the nutrient broth, and the time factor used for comparison of postulant and phenol. Instead of using the 5-minute period, they employ an average of the 2½- and 15-minute periods. They have also introduced the doubtful expedient of unplugged seeding tubes, this being made necessary by the increasing number of dilutions used. This method has been adopted by the committee of the Laboratory Section of the American Public Health Association,[21] but, aside from this, has not as yet found general acceptance.

More recently the Hygiene Section of the Eighth International Congress of Applied Chemistry appointed an international committee to confer with a committee of the Fifteenth International Congress of Hygiene and Dermography, to decide on a standard method for general international use, but as yet no report is forthcoming.

Walker and Weiss[22] have investigated the purity of the phenol control, and have given a new method to insure this, based on the solidifying point of the phenol used as a standard, which should not be below 40° C.

This is the general historical review of the subject, and the writer would now consider the extent to which standardization of disinfectants has been made official, and the logical effect of such official recognition.

Abroad, disinfectant standardization has reached its highest development in England and her colonies. In Germany, France, and other European countries, so far as the writer has been able to learn, there is no official method for standardization and comparison. Doubtless it is carried on, and various methods are used, but the subject on the Continent does not seem to have received the attention it deserves.

This reminds the writer somewhat of a passage in "Innocents Abroad," by the late Samuel Clemens (Mark Twain). He and his party are landing at a certain port, and before being allowed to enter are fumigated. In speaking of it, he says:

"These miserable outcasts called that fumigating us, and the term was a tame one indeed. They fumigated us to guard themselves against the cholera, though we hailed from no infected port. . . . However, they must keep epidemics away somehow or other, and fumigation is cheaper than soap. They must either wash themselves or fumigate other people. Some of the lower classes had rather die than wash, but the fumigation of strangers causes them no pangs."

That is the way many of us feel about disinfection in general: we know it is a good thing, but like the bother and trouble applied to the "other fellow" rather than to ourselves. However, seriously speaking, it is most probable that the more enlightened continental countries, which are under a more or less bureaucratic or autocratic government, can regulate the standard of efficiency of disinfectants to the necessary degree without the measures of popular education necessary in the more individualistic society of countries like England and the United States.

In England the Rideal-Walker test is the universal official standard. Among the British authorities using the Rideal-Walker test to control supplies of disinfectants are the War Office, the Admiralty, the Board of Trade, the India Office, the Office of Works, the Metropolitan Asylums Board, and the cities of London, Westminster, Birmingham, Manchester, Nottingham, Edinburgh, etc. This takes no account of private industrial and semi-public concerns, such as laundries and hospitals, which demand that disinfectants, in common with other purchased supplies, undergo a test to show their actual value for the purposes for which they are intended. The public, too, is educated to the point of knowing what disinfection really means, and the charlatan, imitation articles, which rely on an odor as their recommendation, are mostly reserved for the export trade.

Among the English colonial governments using the Rideal-Walker test as a control may be mentioned Cape Colony, Natal, Western Australia, Victoria, Queensland, Madras, Bombay, Mysore, Shanghai, Hong Kong, etc. Many of the colonial railways also use this method of control in purchases of disinfectant supplies. The Federation of South African States put into effect a very novel and original law. All shipments of disinfectants entering the custom house are subjected to a Rideal-Walker test, and all under 5 have to pay a considerable duty (15 per cent.), while those higher than the figure given come in free. The effect of this law is very well brought out in the following extract from the report of the medical officer of health for Cape Colony for the year 1907:

"Samples of disinfectants submitted by agents tendering for contracts to supply Government departments, as well as samples from all consignments of unknown brands of disinfectants passing through the custom, continue to be examined by the Rideal-Walker test in the Public Health Laboratory.

"No table of the various coefficients obtained during the year is attached to this report, as it was found that some firms were using the published results for the purposes of advertisement.

"The majority of the higher-grade disinfectants have shown a marked rise in the Rideal-Walker coefficient, and from the samples received from the Controller of Customs it would appear that this colony is no longer being made the dumping-ground for worthless, so-called disinfectants, whose only resemblance to germicides consisted in their possessing a strong smell of coal tar, and being able to produce an opaque emulsion when added to water."

This extract shows most clearly that standardization of disinfectants militates against the dishonest manufacturer, to the benefit of the public, and proves that the subject is one well worth serious consideration in this country.

In the United States to-day great interest has been manifested in the question, but so far but one State has taken official cognizance of the subject. This State is Maryland, and the recognition occurs in Regulation No. 2, Labelling of Disinfectants,—State Board of Health, Maryland, revised to May 1, 1911. The portion of interest in this connection reads as follows:

"All disinfectants manufactured or sold in this State must bear a label showing the carbolic acid coefficient or relative germicidal strength of such disinfectants, as compared with pure carbolic acid.

"In determining the relative germicidal value of disinfectants, the application of the Rideal-Walker test to the typhoid bacillus in a 24-hour bouillon culture may be made, and such results will be accepted until further notice.

"The statement of the coefficient should be made as follows:

"Carbolic acid coefficient 0.3, or 1.2, etc., etc.

"This statement may appear on the principal label, or on a supplemental label or sticker."

In the opinion of the writer, every State should have such a law. It should go even further. There should be a national decree compelling the bactericidal efficiency of the articles to be placed upon each package. This would be along the lines of the present Food and Drug Act, or that relating to insecticides and fungicides. Inefficient disinfection is worse than no disinfection at all, and the user should have some real guarantee that the material he uses is capable of accomplishing the work for which it is designed. In the present state of chemical and bacteriological science there is no excuse for this not being brought about.

Antecedent to proper legal measures, it is necessary that a standardized method be adopted by unbiased authorities for use in the various laboratories throughout the country, in order that the method of determination may be incorporated in the various acts and ordinances covering this subject. This is necessary in order to prevent useless confusion and litigation, with consequential unfair evasions by unscrupulous manufacturers and dealers.

To the writer's mind, the method to be selected should have the following features:

1. Well-defined technique.
2. Uniformity of results.
3. Simplicity.
4. Adaptability.

By well-defined technique is meant that all details of the test be clearly set forth and standardized to such an extent that no latitude is allowed the worker, either in the manipulation of the test or in the interpretation of the results. The writer has had considerable experience in standardizing various tests used in the coal-tar industry in this country. These tests are largely physical in their nature, such as distillation work, extraction work, specific gravities, so-called melting point or fusing point of bitumens, etc. The actual figures obtained in these tests are not as important as their comparative character—a means by which buyer and seller can agree upon specifications for products which are of more or less unknown composition, and which consist of a complex mixture of organic compounds. Here it is very necessary that the methods be such that the ordinary workers can obtain concordant results. It is surprising how slight details can cause marked variations in these proximate analyses, and how factors which would not ordinarily be given more than passing notice cause wide deviations between different operators. Only by working out *all* small details, and determining the effect of each minute factor, is it possible to know just which points demand careful attention, and which may be regarded as negligible influences. Any bacteriological test for the purposes which this paper discusses must also pass through such a stage of minute investigation, and emerge, fortified at all points against the differing ideas of various workers as to the essential and the negligible features.

The second requirement, of uniformity of results, is a logical sequel to the first. The only further requisite to this end is that the various workers be so well informed of the necessary details of the test that there is no excuse for deviation or error. If such occur it may be directly chargeable to wilful ignorance on the part of one or the other of the workers.

The third account, "simplicity," is also one of prime importance. If possible, the test should be susceptible of being carried out in the ordinary laboratory, with as little inconvenience and additional apparatus as possible, other than the ordinary bacteriological appliances. It should not be a long, tedious operation, or one requiring specialized training. This is necessary if control is to be constant; in other words, we want accomplishment of results with the minimum effort compatible with accurate and serviceable work. Then, too, if the test is not too long and tedious, there is a greater chance of the worker paying strict and careful attention to those details which are so essential to uniformity.

The fourth and last requirement, "adaptability," is designed to enable the knowledge of disinfectant action to be obtained under special conditions which correspond to the conditions under which the disinfectant is to be used. For ordinary general purposes it would be sufficient to know the coefficient of a disinfectant *per se*,—that is, in presence of bacteria alone, without the addition of organic matter. However, a throat specialist desires to know the disinfecting action in the presence of mucus, the surgeon the action in the presence of blood; the army surgeon, in caring for drainage, must know the value in the presence of feces, urine, etc. Accordingly, in these special cases, mucin, serum, urea, etc., should be added in order to determine their effect. The test should be such that the addition of various materials could be made in the diluent without otherwise changing the technique or introducing needless complications.

Such a method adopted, legislation should follow. Opposition to such legal action could only come from those whose interests were threatened, and this would naturally be those who were selling inefficient disinfectants under false pretences. To-day I believe the public conscience has so developed that such opposition would be given little consideration, once the general public is awakened to the importance of the subject.

As mentioned before, the situation in this country is in the controversial state. The merits of the Rideal-Walker method, and the Hygienic Laboratory method, as proposed by Anderson and McClintic, are undergoing considerable discussion, and the writer feels that it would not be amiss to give here his own opinions and conclusions.

It is far easier to obtain concordant results with the Rideal-Walker method than with the modified method of Anderson and McClintic, and the reason for this is clearly brought out when the count of simplicity is considered.

The writer has had experience with the operation of both methods, and feels that there could be no unbiased critic but would concede at the start that the Hygienic Laboratory method is far more cumbrous, complicated, and involved than is the older method. It may be noticed in the report of the Committee of the Public Health Association (*loc. cit.*) that the inference is made that there were still some considerable discrepancies observed in tests of duplicate samples by different members of the committee. Further work was suggested to determine the cause of the discrepancies. Now, if the members of this committee, who should, supposedly, be the workers *par excellence* in carrying out the method, fail to obtain consistent concordant results, what chance has the "outsider"? It would seem poor policy to indorse a method as a standard, when operators of this high degree of excellence could not consistently check each other's work. The writer feels that this failure is due, in part at least, to the cumbrousness of the Hygienic Laboratory test. English experience has shown that workers *not specially trained* can obtain concordant figures with the Rideal-Walker method.

In carrying out the Rideal-Walker tests there are but five dilutions in all, which means an inoculation only every half minute. This gives ample time for sterilization of the needle, removal of the cotton plugs from the seeding and medication tubes, making the plant, replacing the plugs, setting the tubes back in their places, and taking up a new pair. In the Hygienic Laboratory method, on the other hand, from 10 to 15 dilutions of phenol and postulant are used, thereby allowing but 10 to 15 seconds for all these operations. As this would be physically impossible, open, broad seeding tubes are used, and during the test these are exposed to organisms from the air for a period of 17½ minutes, at the very least, and usually considerably more. Any bacteriologist knows that under such conditions some contamination is not a chance, but a certainty, unless a special sterile, dust-proof room is provided, and even then the difficulties would be very large.

In the Rideal-Walker method, on the other hand, all tubes are sealed with sterile cotton plugs, except at the actual moment of inoculation or sub-culture, and the danger of contamination is reduced to a minimum.

Even with the open seeding tubes, and only 10 dilutions to handle, the Hygienic Laboratory method requires considerable mechanical practice before the operator can begin to perform all the operations and still accurately preserve the time intervals. This is probably one of the principal reasons for discordance in results by this method, and one which cannot be eliminated so long as open seeding tubes are used.

So far as adaptability is concerned, the two methods are equal as regards the introduction of organic matter in the diluent, for this addition occasions no change in their regular technique.

The simplicity of the Rideal-Walker method should, in the writer's opinion, give it the preference over the later proposal of the Hygienic Laboratory, because this simplicity makes it more universally applicable. With it many more consumers would be able to test their disinfectant supplies in their own laboratories. It would be far more to the interest of the general public if the means of ascertaining the truth were more accessible and easy of attainment.

But whichever method prevails, the writer will feel that real progress has been made, and, after all, the end in this case is of far greater importance than the means. Progress will be slower in one case than in the other, but the adoption of some test is imperative.

Much is to be hoped from the committee recently appointed by the Eighth International Congress of Applied Chemistry, which will co-operate with the committees of the Fifteenth International Congress on Hygiene and Dermography. Unfortunately, this joint committee is not required to report for three or four years,—that is, before the next Congress. The writer hopes that, so far as this country is concerned, this much-needed reform will not be delayed so long. Let us hope that a method, acceptable to all workers in this country, will be chosen for use as a control over the bactericidal efficiency of various preparations and compounds offered for purposes of disinfection.

This accomplished, it will be the duty of true scientific men to spare no effort and waste no opportunity to demonstrate to the public at large the need and use of this subject. If the public is once awakened in this country, legislation will surely follow, and we will compel honesty and real merit in all disinfectants, a subject for a long time a mystery to the layman and to the average physician and health officer, which has been accepted rather on faith than upon knowledge.

It will be an incalculable gain for preventive medical science, for sanitation, and for the health of the public at large. It will do its share toward elimination of disease and suffering, and serve to shield the careful individuals from the ignorant carelessness of others.

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[22] Walker and Weiss: JOURNAL OF THE FRANKLIN INSTITUTE, July, 1912.

Number of β-Particles Emitted in the Transformation of Radium. H. G. J. MOSELEY. (*Roy. Soc. Proc., Ser. A,* lxxxvii, 230.)—The recent researches of v. Baeyer, Hahn, and Meitner show that the β-radiation from a substance can generally be resolved by a magnetic field into several distinct groups of approximately homogeneous rays. Danysz has shown that more than 23 such groups are present in the radiation from RaB and RaC. It is, therefore, interesting to know the number of β-particles emitted from each disintegrating atom evolved by these products. Two methods were used for determining this number. In the first the particles were collected in a brass box thick enough to stop them all, and the number deduced from the negative charge acquired by the box. In the second method there was measured the positive charge gained by the active material (the α-particles being absorbed) as the result of the loss of the β-particles. The number of disintegrating atoms was deduced from the α-particle measurements of Rutherford and Geiger. The results show that each atom of RaB and of RaC emits, on disintegration, probably one β-particle, though the measurement gave 1.1 as the average number. Each atom of RaE appears to emit less than one β-particle. The absorption of the β-radiation from the active deposit was studied, measurements being made both of the number of β-particles penetrating the absorbing material and of the ionization they produce. With the help of the data obtained by Geiger and Kovarik the number of β-particles emitted on disintegration by atoms of UrX, ThD, and AcD were estimated at 1, 0.8 and 1.4 respectively. It is deduced that each atom of RaC emits two γ rays on disintegration.

Disadvantages of the New American Standard Copper Specifications. E. A. LEWIS. (*Met. and Chem. Eng.,* x, 540.)—The new standard proposed by the American Society for Testing Materials, although it has met with approval by many American users and manufacturers of copper, is most unsatisfactory as compared with the high-class copper approved by English users and makers. Its lays too great stress on the electrical conductivity test. The cause of this is, probably, the adoption of electrolytic methods of refining on a vast scale in America, producing very pure copper, excellent for wire and brass alloys of high conductivity, but inferior for wearing purposes, and this specification bars tough, arsenical copper, which has valuable properties and distinct uses. A point apparently overlooked by the American committee is that it is impossible to work the non-arsenical oxygen copper they recommend. For electrical work the specification is important, but for copper, for sheets, tubes, rods, etc., it is considered valueless and even misleading. It is suggested that bending tests, opening tests, tensile tests, and limitations in the amount of impurities are required.

RECENT DEVELOPMENTS IN STEAM TURBINES.*

BY

H. T. HERR,
Vice-President and General Manager, The Westinghouse Machine Company.

In Fig. *c*, as has been previously shown for the PV diagram, $q = \frac{xy}{xz}$ for the point y.

On the ϕT diagram, Fig. *d*,

$$\varphi_w = \log \frac{T}{493}$$

$$\phi_s = \phi_w + \frac{qL}{T}$$

$$\phi \text{ dry} s = \theta_w + \frac{L}{T}$$

But,

$$ea = \varphi_w$$

$$eb = \phi_s = \varphi_w + \frac{qL}{T}$$

$$ac = \frac{L}{T}$$

$$\therefore q = \frac{ab}{ac}$$

Not the least merit of the ϕT diagram as a means of graphically representing the cycle of operations in a heat engine is, that it shows the heat taken in and the heat rejected, as well as the work done, and so allows estimates of efficiency to be made by inspection of the diagram itself.

XLII. In steam turbine work the energy of the expanding steam is extracted from its velocity through various stages of its more or less approximate adiabatic expansion.

In Fig. *e* an entropy-temperature diagram is plotted for 1 pound of steam which is expanded adiabatically from the point a with T_1 temperature and P_1 pressure and dryness $q = 1$ to b at T_2 temperature and P_2 pressure.

The available energy or work that can be done by a perfect engine under these conditions is represented on the diagram by the area $a\,b\,c\,d\,a$.

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[*] Concluded from page 530.

From the first equation of thermodynamics—

$$E'' - E' = -W + Q$$

But $a\,b\,c\,d\,a$ is a cyclic process—

$$\begin{aligned}
&\therefore E'' - E' = 0 \\
&\therefore W = Q \\
&W = Q = \text{area } a\,b\,c\,d\,a \\
&\quad = \text{area } o\,e\,c\,d\,a\,b\,f - \text{area} \\
&\quad\ o\,e\,c\,b\,f = \text{area } o\,e\,c\,d\,a\,b\,f - \\
&\quad\ [\text{area } o\,e\,c\,b'\,f' - \text{aree } b\,b'f'f] \\
&H_1 = h_1 + L_1 = \text{area } o\,e\,c\,d\,a\,b\,f \\
&H_2 = h_2 + L_2 = \text{area } o\,e\,c\,b'f' \\
&(\phi_2 - \varphi_1)T_2 = \text{area } b\,b'f'f
\end{aligned}$$

$$\therefore W = Q = H_1 - H_2 + (\phi_2 - \phi_1) \text{ in B. T. U. per pound of steam.}$$

FIG. *c*.

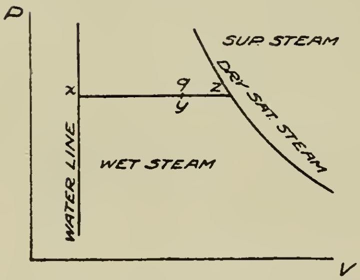
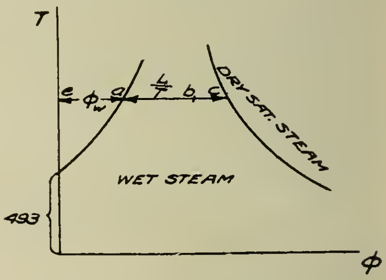


FIG. *d*.



If all this energy could be turned into velocity, the following well-known formula from mechanics for unit mass would give the available velocity of the steam issuing from a suitable nozzle:

$$\frac{V^2}{2g} = W \text{ (foot-pounds)} = Q \text{ (B. T. U.)} \times 778,$$

or, $V = \sqrt{778 \times 2gQ} = 223.7\sqrt{Q}$

when V = velocity of the jet in feet per second
g = acceleration due to gravity in feet per second.

Similarly, for adiabatic expansion of steam initially wet or with dryness q as represented in Fig. *f*:

$$W = Q = H_1 - H_2 + (\phi_2 - \phi_1)T_2 - (\phi_1 - \phi_g)(T_1 - T_2)$$

XLIII. The available energy of superheated steam expanding adiabatically between certain ranges of temperature is more difficult of calculation than the two preceding cases of dry saturated and wet steam. With the aid of the entropy-temperature diagram, formulæ for the three cases of superheated steam may be deduced as follows:

Case I.—When the superheat is just sufficient to bring the adiabatic expansion to the lower temperature of the cycle at the time the steam becomes dry and saturated. Let Fig. *g* represent an ϕT diagram in which *a d a a′ b′ b c* represents the work done. The line *a a′* represents the process of superheating from T_1 temperature to T_3 temperature.

FIG. *e*.

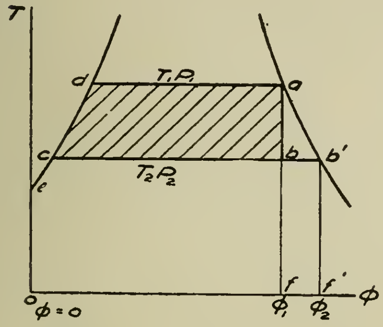
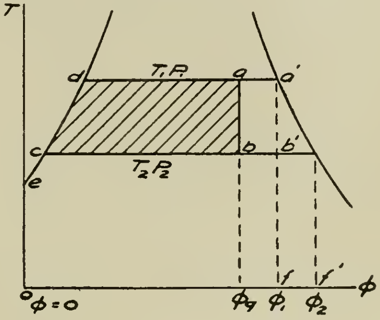


FIG. *f*.



From what has preceded—

$$E'' - E' = - W + Q.$$

This being a cyclic process—

$$E'' - E' = 0 \therefore W = Q.$$
$$H_1 = \text{area } o\,e\,c\,d\,a\,b\,f\,o$$
$$H_2 = \text{area } o\,e\,c\,b\,b'\,f'\,o$$

The work done or available energy from the superheat is:

$$\text{area } f\,b\,a\,a'\,b'\,f' - \text{area } f\,b\,b'\,f'.$$

But area *f b a a′ b′ f′* = area under the curve *a a′*, which, as has been shown, is equal to $\int T\,d\phi$. (See proof that $\frac{d\phi}{dQ} = \frac{1}{T}$)

$$\therefore Q = \text{area } c\,d\,a\,a'\,b'\,c = H_1 - H_2 + \int_{\phi_3}^{\phi_1} T d\phi$$

Case II.—When the superheat is not sufficient to bring the adiabatic expansion to the lower temperature without the presence of wet steam. Let Fig. *h* represent an ϕT diagram in in which *c d a a′ b′ b c* represents the work done.

The line $a\,a'$ represents the process of superheating from T_1 temperature to T_3 temperature.

As before—

$$
\begin{aligned}
E'' - E' &= 0\\
W &= Q \text{ (cyclic process)}\\
H_1 &= \text{area } o\,e\,c\,d\,a\,b\,f\,o\\
H_2 &= \text{area } o\,e\,c\,b''\,f''\,o
\end{aligned}
$$

The available energy from the superheat is—

$$\text{area } f\,b\,a\,a'\,b'\,f' - \text{area } f\,b\,b'\,f'\ (\phi_2 - \phi_s)\ T_2 = \text{area } f'\,b'\,b''\,f''$$

$$\int_{\phi_8}^{\phi_1} T d\phi = \text{area } f\,b\,a\,a'\,b'\,f'$$

$$\therefore W = Q = \text{area } c\,d\,a\,a'\,b'\,b\,c = H_1 - H_2 + \int_{\phi_8}^{\phi_1} T d\phi + (\phi_2 - \phi_8)\ T_2$$

FIG. *g*.

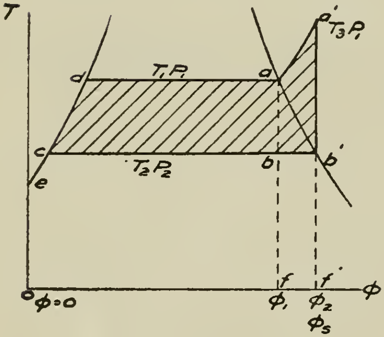
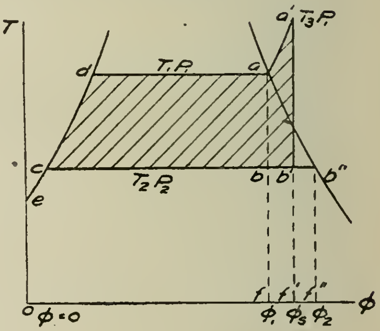


FIG. *h*.



Case III.—When superheat is still present after adiabatic expansion to the lower temperature at which condensation takes place. Let Fig. *i* represent an ϕT diagram in which $c\,d\,a\,a'\,b'\,b''\,c$ represents the work done, and let the adiabatic expansion from a' to b' bring the steam at temperature $T > T_2$ into the condenser.

As before—

$$
\begin{aligned}
E'' - E' &= 0\\
\therefore W &= Q \text{ (cyclic process).}\\
H_1 &= \text{area } o\,e\,c\,d\,a\,b\,f\,o\\
H_2 &= \text{area } o\,e\,c\,b''\,f''\,o
\end{aligned}
$$

The available energy from the superheat is area $f\,b\,a\,a'\,b'\,h\,f'\,f$ − area $f\,b\,b''\,h\,f'\,f$ − area $b''\,b'\,h$ $(\phi_s - \phi_2)\,T_2$ = area $f''\,b''\,h\,f'$

$$\int_{\phi_s}^{\phi_1} Td\phi = \text{area } f\,b\,a\,a'\,b'\,h\,f'\,f$$

$$\int_{\phi_s}^{\phi_2} Td\phi = \text{area } f''\,b''\,b'\,h\,f'\,f''$$

$$\therefore W = Q = \text{area } c\,d\,a\,a'\,b'\,b''\,b\,c =$$

$$H_1 - H_2 + \int_{\phi_s}^{\phi_1} Td\phi - \int_{\phi_s}^{\phi_2} Td\phi + (\phi_s - \phi_2)\,T_2$$

The five cases for wet, dry saturated, and superheated steam as to the available energy during adiabatic expansion are covered by the following formulæ:

Case I.—Wet steam expanding adiabatically—

$$W = Q = H_1 - H_2 + (\phi_2 - \phi_1)\,T_2 - (\phi_1 - \phi_q)\,(T_1 - T_2)$$

Case II.—Dry saturated steam expanding adiabatically—

$$W = Q = H_1\,H_2 + (\phi_2 - \phi_1)\,T_2$$

Case III.—Superheated steam expanding adiabatically when $\phi_s = \phi_2$—

$$W = Q = H_1\,H_2 + \int_{\phi_s}^{\phi_1} Td\phi$$

Case IV.—Superheated steam expanding adiabatically when $\phi_s < \phi_2$—

$$W = Q = H_1 - H_2 + \int_{\phi_s}^{\phi_1} Td\phi + (\phi_2 - \phi_s)\,T_2$$

Case V.—Superheated steam expanding adiabatically when $\phi_s > \phi_2$—

$$W = Q = H_1 - H_2 + \int_{\phi_s}^{\phi_1} Td\phi - \int_{\phi_s}^{\phi_2} Td\phi + (\phi_s - \phi_2)\,T_2$$

XLIV. The five cases of adiabatic expansion discussed in the preceding section give a cycle of operations, commonly known as the "Rankine Cycle," which, on a pressure volume diagram, is represented as in Fig. *j*.

A cylinder and piston of perfect non-conducting material are assumed, into which cylinder steam is admitted at an initial pressure P_1 and temperature T_1. This steam is allowed to expand adiabatically until its pressure and temperature are P_2 T_2. On the return stroke of the piston, the steam is exhausted to the condenser at temperature T_2, and after exhaust, and without clearance, steam is again admitted from the source of supply, thus completing the cycle.

By the first law of thermodynamics, the difference between the heat supplied to an engine and the heat rejected is equivalent to the work done, provided there are no losses. It therefore follows that in a steam engine working on Rankine's cycle the heat converted into work is equal to the difference in the heat contents of the steam supplied to and exhausted by the engine. This consideration is used in the discussion of the relative merits of steam turbines as to their efficiency by referring their performance to that of a steam engine using Rankine's cycle, and the efficiency of a turbine is generally stated as a per cent. of that conversion of heat into work that could be obtained if the Rankine cycle were fulfilled.

FIG. *i*.

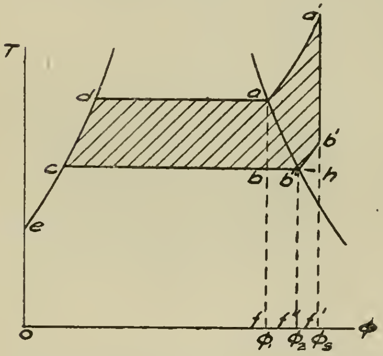
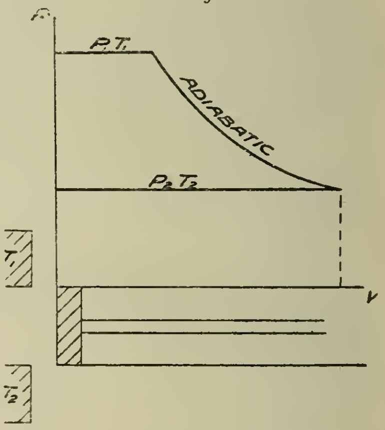


FIG. *j*.



APPENDIX II.

Designs of Drums and Disks for Rotors of Steam Turbines.

I. DRUM DESIGN.

The general method of procedure is to calculate first the stress in the drum, due to its own mass and velocity, then the additional stress due to the centrifugal force of the blades and their accessory parts, such as packing pieces, lashing, and shrouding.

The stress in a rotating ring of steel, of very small radial thickness, is given by the equation

$$f_t = .106\ v^2 \tag{1}$$

where f_t = the tangential or " hoop " stress, and v the velocity in feet per second. If the ring has a radial thickness that is not small compared with the radius, this formula does not apply with accuracy. If the radial thickness is not more than one-third the outside radius, a very good approximation may be made by applying the formula (1) with v as the velocity at the mean radius, in which case f_t is to be taken as the mean tangential stress, or the stress at the mean radius; and the stress at any other radius is nearly inversely proportional to that radius. In the case of a thin disk of uniform thickness with radial width .4 of the outside radius, the stress at the inner radius calculated in this way is about 3 per cent. lower than that obtained by the more refined analysis. In the case of the drum the error is somewhat greater, with the assumed radial thickness; but as practically all drums have a radial thickness not more than half that assumed above, the error in such cases due to the above method becomes practically negligible.

The method described, while based on the accepted methods of exact analysis, may be approximately derived as follows: In the disk or drum having a relatively large bore, the radial stresses may be neglected, and hence the radial stretch also; and as all the ideal component hoops or drums of very small thickness thus have the same circumferential stretch, the tangential stress at any radial distance is inversely proportional to the radius.

In determining the drum stress due to the blading, etc., the centrifugal forces of these parts are first found by the well-known formulæ. The total centrifugal load of blades, etc., on any part of the length of the drum when divided by $2\ \pi$ gives the corresponding pull on the cross section of that part of the drum. This pull is further reduced to a mean stress by dividing by the sectional area, and this mean stress is again taken as the actual stress (due to blades) at the mean radius of the drum. The stress at the inner radius is inversely proportional to that radius, as in the case of the unloaded drum. Finally, the total stress at the inner radius is found as the sum of the stresses due to the blade and drum itself.

The effect of the blade loads in stressing the drum as described above is a close approximation, based on the more exact analysis of the drum considered as a " thick tube " with external load.

2. DISK DESIGN.

Taking the most general case, that of a disk with a wide rim, the design procedure is as follows: Having determined the necessary section of the rim to suit the blading: First find the mean stress in the rim alone as if it were free from the internal disk, by the method for drums described above. This imaginary stress f_1 is to be reduced by the action of the disk, exerting an inward radial pull on the rim. Assuming that the design of the disk is to be such as to give as nearly as possible uniform stress in both the tangential and radial directions, it is to be noted that the stretch at the outer edge of the disk is but $1 - d$ times that of the rim, where d is Poisson's ratio (about .3 for steel). Hence the hoop stress in the rim is taken at .7 of the uniform stress in the disk. Having decided upon the permissible stress f, the radial pull between the disk and the rim is that corresponding to a mean hoop stress $f_1 - .7\ f$ in the rim, and from this with the given stress f the thickness y_n required for the disk at its junction with the rim is readily found.

From this thickness as a starting point the design of the disk proper proceeds as follows: If the disk is not to be pierced for a shaft, the formula of De Laval applies, giving practically uniform stresses.

$$\mathrm{Log}_{10}\frac{Y}{Y_n} = .434\,\frac{K}{2f}\left(r_n^2 - r^2\right) \qquad (2)$$

in which,

Y = thickness of the disk at any radius r.
Y_n = thickness of the disk at the outer radius r_n
f = the permissible stress.
K = the centrifugal force per cubic unit of the material at unit radius at the given angular velocity.

If a disk is pierced with a small hole at the centre, the tangential stress at the bore is double that in the unpierced disk; as the bore is made larger the stress increases still further. It can be shown that it is impossible to design a pierced disk so that the radial and tangential stresses are everywhere equal, as in the disk shaped by the De Laval formula. For the safety of the pierced disks the thickness is generally increased toward the centre at a faster rate than that given by the De Laval formulæ, and a hub is provided for additional strength partly because of the necessary grip on the shaft. The necessary keyways in the bore still further complicate the stress conditions. There are no simple formulæ on generally-accepted methods fully covering the design of pierced disks; the thickening of the web and the addition of the hub are to a large extent empirical and governed by the judgment of the designer.

APPENDIX III.

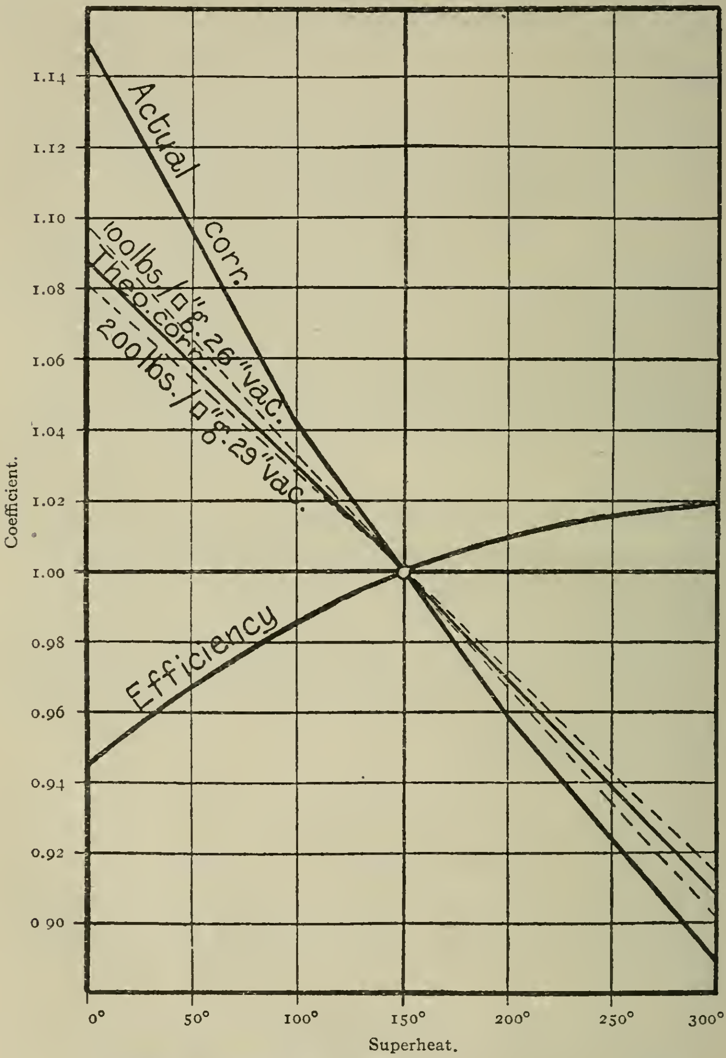
1. *Corrections for Turbines Designed for Particular Conditions.*

(*a*) *Steam Quality.*—For complete expansion, low-pressure, and non-condensing turbines, the corrections are as follows: Between—

0–100° F. superheat, 1 per cent. improvement of steam consumption for every 10° F. superheat.
100–200° F. superheat, 1 per cent. improvement of steam consumption for every 12° F. superheat.
200–300° F. superheat, 1 per cent. improvement of steam consumption for every 14° F. superheat.

The efficiency increases with the superheat, and consequently the actual is larger than the theoretical correction, which is calculated from the variations of the available heat drop in adiabatic expansion. Fig. *a* plots the actual superheat corrections

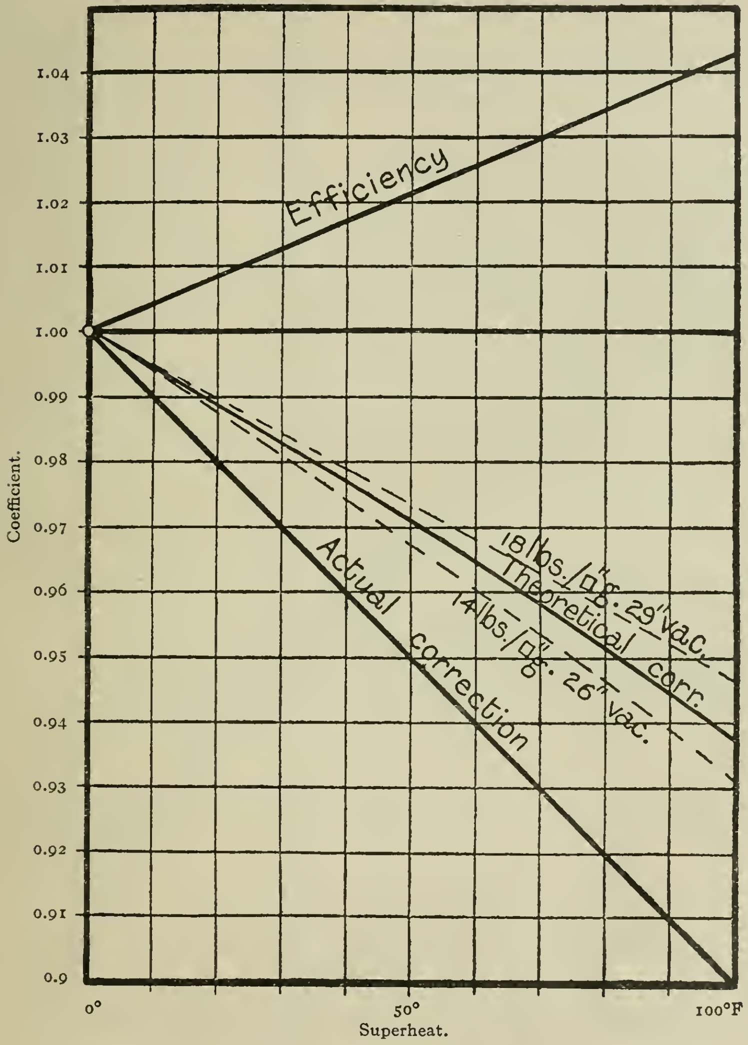
FIG. a.—APPENDIX III.



Superheat corrections for high-pressure turbine designed for superheat.

for high-pressure turbines, together with the change of efficiency and the mean theoretical correction for steam conditions varying

FIG. b.—APPENDIX III.

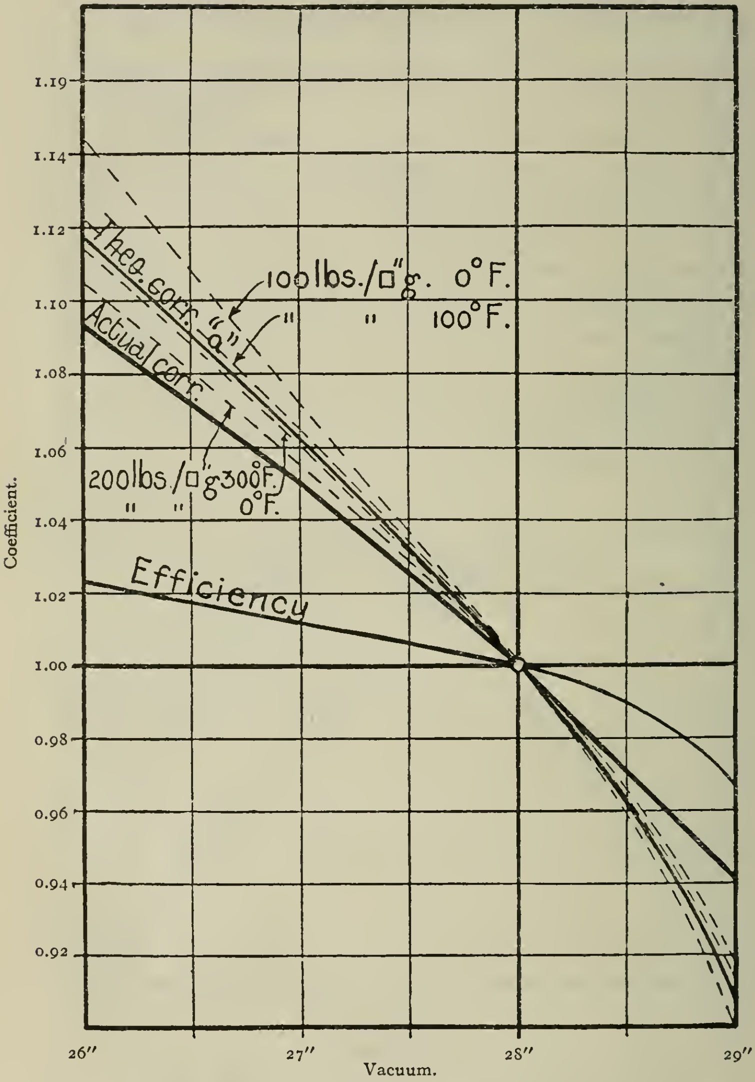


Superheat corrections for low-pressure turbine designed for superheat.

between the limits 100 pounds per square inch gauge pressure, 26 inches vacuum, and 200 pounds per square inch gauge pressure, 29 inches vacuum.

Fig. *b* plots similar values for low-pressure turbines for conditions varying between the limits 14 pounds per square inch

FIG. c.—APPENDIX III.



Vacuum corrections for high-pressure turbine designed for vacuum.

absolute pressure, 26 inches vacuum, and 18 pounds per square inch absolute pressure, 29 inches vacuum.

The improvements in efficiency may be taken as 4.25 per cent. better efficiency at 100° F. superheat than for dry saturated steam; 6.75 per cent. better efficiency at 200° F. superheat than for dry saturated steam; 7.5 per cent. better efficiency at 300° F. superheat than for dry saturated steam, from which the futility of comparing the efficiencies of turbines, without taking into account the superheat conditions in operation, is apparent.

Tests have shown that when steam is wet the efficiency is reduced. Assuming that the efficiency follows a continuous curve for superheat and wet steam when plotted with entropy as the basis, the efficiency will change by one per cent. for each one per cent. variation in wetness. It follows, therefore, that the steam consumption measured as condensed water will be two per cent. higher for each one per cent. increase in moisture.

(*b*) *Vacuum.*—Fig. *c* plots the vacuum corrections for complete expansion turbines. The average theoretical corrections obtained by considering the adiabatic heat drop available may be taken as:

5 per cent. improvement of steam consumption for 1 inch between 26 inches and 27 inches vacuum.
6 per cent. improvement of steam consumption for 1 inch between 27 inches and 28 inches vacuum.
7.75 per cent. improvement of steam consumption for 1 inch between 28 inches and 28½ inches vacuum.
11.5 per cent. improvement of steam consumption for 1 inch between 28½ inches and 29 inches vacuum.

The actual improvement which can be obtained in present turbine design is:

4 per cent. improvement of steam consumption for 1 inch between 26 inches and 27 inches vacuum.
5 per cent. improvement of steam consumption for 1 inch between 27 inches and 28 inches vacuum.
6 per cent. improvement of steam consumption for 1 inch between between 28 inches and 29 inches vacuum.

According to these figures, the efficiencies of equivalent complete expansion turbines designed to utilize different vacua would be:

1 per cent. better efficiency at 26 inches than at 27 inches.
1 per cent. better efficiency at 27 inches than at 28 inches.
1 per cent. better efficiency at 28 inches than at 28½ inches.
2.5 per cent. better efficiency at 28½ inches than at 29 inches.

These figures represent a fair average for steam conditions between the limits of steam pressure at 100 pounds per square inch gauge to 200 pounds per square inch gauge; superheat 0° F. to 300° F.

While the superheat correction is nearly independent of other steam conditions, the vacuum correction depends to a great extent upon the steam pressure, and is much larger for low-pressure turbines, the corrections for which are plotted in Fig. *d*.

For low-pressure turbines, the average theoretical corrections are:

12 per cent. improvement of steam consumption for 1 inch between 26 inches and 27 inches.
13.75 per cent. improvement of steam consumption for 1 inch between 27 inches and 28 inches.
17 per cent. improvement of steam consumption for 1 inch between 28 inches and 28½ inches.
22.5 per cent. improvement of steam consumption for 1 inch between 28½ inches and 29 inches.

The actual improvements which can be obtained with the present low-pressure designs are:

11.5 per cent. improvement of steam consumption for 1 inch between 26 inches and 27 inches vacuum.
13 per cent. improvement of steam consumption for 1 inch between 27 inches and 28 inches vacuum.
14.5 per cent. improvement of steam consumption for 1 inch between 28 inches and 29 inches vacuum.

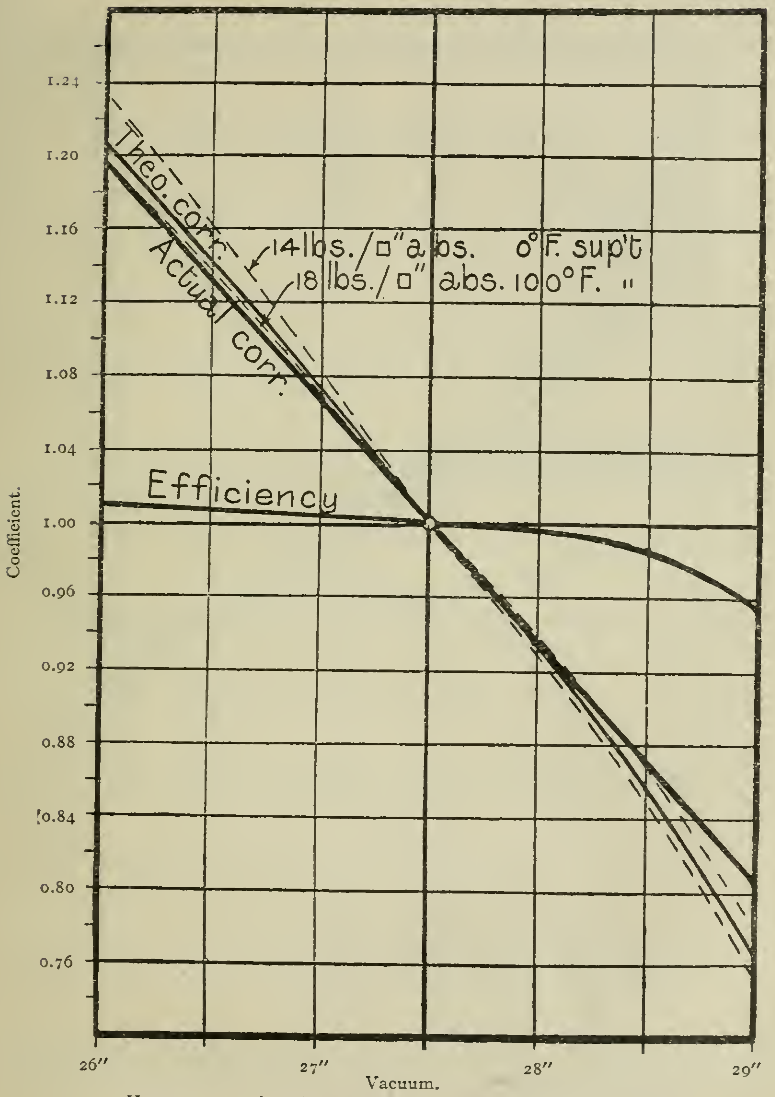
According to these figures, low-pressure turbines using and designed to utilize different vacua efficiencies as follows:

0.5 per cent. better efficiency at 26 inches than at 27 inches.
0.7 per cent. better efficiency at 27 inches than at 28 inches.
1.0 per cent. better efficiency at 28 inches than at 28½ inches.
3.5 per cent. better efficiency at 28½ inches than at 29 inches.

The corrections given represent a fair average for any steam conditions between the limits:

14 pounds per square inch absolute 0° F. superheat.
18 pounds per square inch absolute 100° F. superheat.

FIG. d.—APPENDIX III.

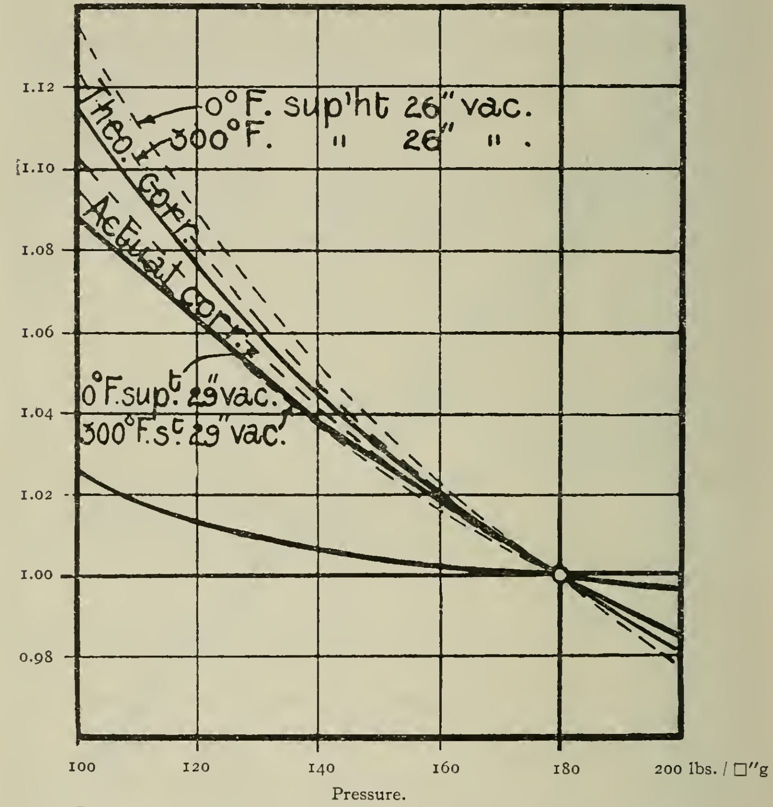


Vacuum corrections for low-pressure turbine designed for vacuum.

(*c*) *Pressure.*—The efficiency which can be obtained with turbines having the same number of stages depends also, but in a lesser degree, upon the steam pressure.

The corrections for pressure in the case of complete expansion turbines are shown in Fig. *e*. The average theoretical corrections are as follows:

FIG. e.—APPENDIX III.



Pressure correction for high-pressure turbine designed for the pressure.

2 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 100 and 140 pounds per square inch gauge.

1.95 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 140 and 180 pounds per square inch gauge.

1.90 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 180 and 200 pounds per square inch gauge.

The actual improvements in steam consumption which can be obtained are:

1.5 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 100 and 200 pounds per square inch gauge.

According to these figures, equivalent high-pressure turbines having the same number of stages, using and designed to utilize different pressures, would give improved efficiencies as follows:

0.4 per cent. better at 180 pounds per square inch than at 200 pounds per square inch gauge.
1.0 per cent. better at 140 pounds per square inch than at 180 pounds per square inch gauge.
1.6 per cent. better at 100 pounds per square inch than at 140 pounds per square inch gauge.

These corrections are a fair average for any steam conditions between 0° F. superheat, 26 inches vacuum, and 300° F. and 29 inches vacuum. For low-pressure turbines the consumption correction is plotted in Fig. *f*.

The range of pressure met with in low-pressure turbines is so small that a pressure correction for the Rankine-cycle efficiency is negligible. The average consumption correction is as follows:

4 per cent. improvement for 10 per cent. increase in pressure between 14 and 18 pounds absolute.

These figures may be taken as a fair average between the limiting steam conditions 0° F. superheat, 26 inches vacuum, and 100° F. superheat, 29 inches vacuum.

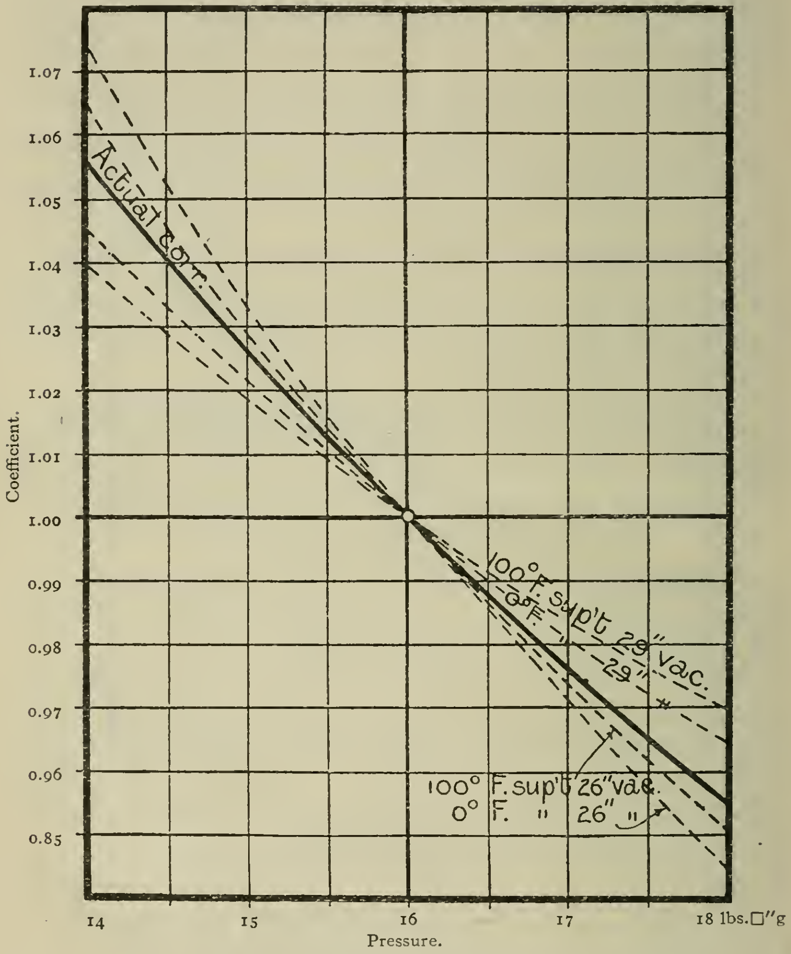
All the corrections referred to above are for steam consumptions of turbines utilizing steam conditions for which they have been specially designed, and are of the greatest importance to the purchaser when fixing steam conditions under which turbines are to operate. In addition to the above corrections, however, the following must be considered:

2. CORRECTIONS FOR TURBINES RUNNING UNDER CONDITIONS DIFFERENT FROM THOSE FOR WHICH THEY HAVE BEEN DESIGNED.

(*a*) *Steam Quality.*—When a turbine designed for definite conditions of load, pressure, superheat, and vacuum is tested at conditions other than those for which it has been designed, there must be a variation in the operating conditions.

The superheat corrections for steam consumptions, measured at certain specific full loads or partial loads, are the same as those already given for turbines designed for different superheats, *i.e.*,—

FIG. f.—APPENDIX III.



Pressure correction for low-pressure turbine designed for the pressure.

1 per cent. improvement of steam consumption for every 10° F. superheat between 0–100° F.

1 per cent. improvement of steam consumption for every 12° F. superheat between 100–200° F.

1 per cent. improvement of steam consumption for every 14° F. superheat between 200–300° F.

Also the corrections for wetness remain the same as above given.

(*b*) *Vacuum.*—An improvement in vacuum of a turbine designed for certain operating conditions will cause a decrease in steam consumption, at the same time increasing its capacity.

If, for instance, an improvement in the vacuum from 27 inches to 28 inches causes a decrease in the steam consumption of 5 per cent., the steam pressure on the initial stages of the turbine will also drop 5 per cent.

The turbine will then be 5 per cent. too large for these conditions, and the steam will be throttled to a greater extent than if the turbine had been designed for 28 inches vacuum. The improvement due to vacuum will therefore be smaller than that already given for turbines designed for various vacua. In the case cited, a 5 per cent. decrease in pressure would, for complete expansion turbines, decrease the improvement due to vacuum by one-half of 1 per cent.

The improvement will be further decreased because the efficiency of the last stages being designed for 27 inches, and working with 28 inches vacuum, will be inferior to that of stages designed to properly handle the larger steam volumes at 28 inches vacuum.

It is apparent, therefore, that the decrease in the steam consumption of a turbine for an increase in vacuum will depend upon the vacuum for which the turbine has been designed.

The correction for partial loads becomes larger for two reasons: (*a*) as the available heat drop becomes less, the change due to vacuum becomes greater; and (*b*) as the total weight of steam flowing through the turbine becomes less, the blading of the last stages is better able to handle the increased volume due to increased vacuum.

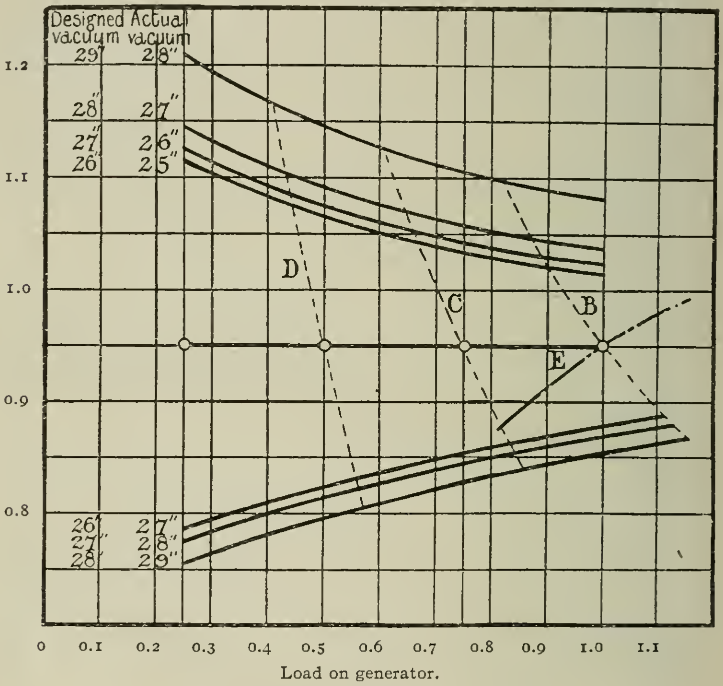
For these reasons, the corrections will be still larger for mixed-pressure turbines where the low-pressure part is too large for the steam quantity used when running on high-pressure steam.

For low-pressure turbines working with vacua other than those for which they were designed, the correction is still greater. If, for example, an improvement of vacuum from 27 inches to 28 inches decreases the steam consumption 13.75 per cent., the steam pressure on the initial stages falls by 13.75 per cent.

As a pressure decrease of 10 per cent. on low-pressure turbines increases the steam consumption by 4 per cent., the correction is reduced from 13.75 per cent. to about 9.5 per cent.

The actual corrections for different loads of turbines designed from 26 inches, 27 inches, 28 inches, and 29 inches vacuum are plotted in Fig. *g* for 1 inch change in vacuum above or below that for which the turbine is designed. When a turbine designed for a given vacuum is run at a lesser one, it will not supply the designed full load with the full-load pressure. The total steam quantity remains the same, but since the available heat drop is reduced, the work done will also be reduced. If, for example, a turbine is designed for 26 inches vacuum and is run at 25 inches vacuum, the maximum load at this vacuum will be only 90 per cent. of the designed full load at 26 inches vacuum. The designed full load can, however, be obtained by raising the pressure on the initial stages.

FIG. g.—APPENDIX III.



Vacuum correction for low-pressure turbines.

The maximum loads which can be obtained with a vacuum 1 inch above or below that for which a turbine is designed, provided the pressure on the initial stages remains the same, are given by Curve *B* in Fig. *g*. Curves *C* and *D* similarly connect points corresponding to three-fourths maximum load and one-half maximum load.

The intercept corresponding to a maximum load and the Curve *E* gives the ratio of the steam consumption at that maximum load to the consumption of the full load and vacuum for which the turbine is designed.

Pressure Correction.—When the steam pressure on the initial stages is increased, the steam consumption decreases because of the increase of available energy. For high-pressure turbines the improvement of steam consumption is 1.5 per cent. for 10 per cent. increase of pressure. For low-pressure turbines the improvement of steam consumption is 4 per cent. for 10 per cent. increase of pressure.

If, however, the turbine is working on constant load and the pressure before the governor valve is increased, the pressure on the initial stages of the turbine remains practically constant, and the only advantage gained is that due to the increased superheat resulting from throttling the steam.

In this case the corrections for full or partial loads will be the same for high-pressure and low-pressure turbines, namely, one-half of 1 per cent. improvement of steam consumption for every 10 per cent. increase of pressure.

Iron-carbon and Iron-silicon Alloys. E. GUMLICH and P. GOERENS. (*Faraday Soc. Trans.*, viii, 98.)—An extensive series of tests has shown that the presence of large amounts of silicon prevents, even with rather quick cooling, the formation of the extremely injurious solid solution of carbon and iron, the carbon appearing only in the shape of the much less injurious pearlite. Under the influence of silicon, even the pearlite is decomposed by a prolonged process of annealing into ferrite and temper-carbon, and thus becomes almost entirely passive magnetically. To produce this effect with certainty, at least from three to four per cent. of silicon is necessary in the material. The fact that thin sheet metal containing carbon and less than three per cent. of silicon may show exceedingly good magnetic properties must have other reasons.

Crystolon—Silicon Carbide. F. A. J. FITZGERALD. (*Met. Chem. Eng.*, x, 519.)—At sufficiently high temperature in an oxidizing atmosphere crystolon decomposes to form SiO_2 and CO, or, in a neutral or reducing atmosphere, to form Si vapor and C in the form of the original crystals. Great care is required in mixing up the charge, viz., 60 SiO_2 and 36 C, for a slight excess of SiO_2 in any part of the furnace results in the formation of Si. The working temperature range is about 400°, below which the reaction does not begin and above which the SiC is decomposed with a loss of Si, and, if the temperature becomes sufficiently high, the formation of graphite. The furnace, which takes about 700 kilowatts, starting at 215 volts and ending with 9000 ampères at 80 volts, and a power factor of 0.9, is built up with the charge surrounding a horizontal core of granular coke resistor.

Production of Pig Iron in 1912. ANON. (*Board of Trade J.*, Feb. 20, 1913.)—According to a Bulletin issued by the American Iron and Steel Institute, the production of pig iron in the United States in 1912 was as follows; the figures for 1911 and 1910 are given for comparison:

	1910 Tons	1911 Tons	1912 Tons
Bessemer and low phosphorus	11,245,642	9,409,303	11,667,656
Basic	9,084,608	8,520,020	11,394,477
Charcoal	396,507	278.676	347,025
Ferro-manganese	71,376	74,482	125,379
Spiegeleisen	153.055	110,236	96,346
Foundry ferro-silicon, etc.	6,352,379	5,256,830	6,096,254
	27.303.567	23,649,547	29,727,137

Absorption of Creosote by the Cell-walls of Wood. C. H. TEESDALE. (*U. S. Dept. Agric.*, Circular No. 200.)—The location of the creosote absorbed by wood is important in so far that if the cell-walls absorb creosote a weakening effect may be expected similar to that produced by moisture in wood. A number of samples of wood dried in an oven at 100° C. for 24 hours were treated with creosote for 1½ hours at 82° C. and a pressure of 150 pounds per square inch, and then raised to a temperature of 104.5° C. for 5 hours. The volume of the samples was measured before and after treatment, and the following average increases in volume noted: Yew—Heartwood 6.81, sapwood 10.70. Hemlock—Heartwood 7.30. Hard Maple—Heartwood 8.14 per cent. It follows that a decided swelling occurs in wood impregnated with creosote. The tests indicate that this swelling is caused by the absorption of the creosote by the cell-walls.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SCALES AND WEIGHING MACHINES.

In the next fiscal year, beginning July 1, the Bureau will have an appropriation of $25,000 for an equipment for standardizing large scales, such as track scales, etc.

This equipment will serve, first, to furnish standard weights of large size for standardization purposes; secondly, it will be used in conducting investigations and experiments upon the large scales and weighing machines.

As a standard it will be used as a means of standardizing the master scales used by the officials of States who are authorized to test railroad and warehouse scales; and as a standard for master scales of railroads and other concerns who employ such a scale for standardizing the weight of the test weight cars used for adjusting the regular service scales.

The equipment will also be available for determining the condition of scales in cases of disputes in commercial transactions in which weights are involved, and so provide equitable means of settlement.

The investigations will include the test of scales used in the regular railroad and warehouse service, in order to determine the accuracy of scales used under various circumstances.

The scales will be studied to determine the value and reliability of the various designs of scales and the efficiency of various systems of inspection, test, and maintenance. These data will be used in assisting the development of uniform and reliable specifications for the design and maintenance of scales, and so further establish accurate weights in commercial transactions.

Wagon and warehouse scales are generally tested with a load which is but a fractional part of their capacity. The test equipment will be used to test these scales under full load. The data obtained will be used in establishing necessary value of the test load required to insure the proper action of the scale at full load. In order to be independent from master scales, etc., the equipment will consist of test weights aggregating 100,000 pounds. The weights will consist of 10,000 pounds of 50-pound weights, four 2500-pounds weights, and eight 10,000-pound weights. A truck will be provided for carrying the weights while they are being shifted from point to point upon track scales during the test. The weights and truck will be housed and transported in a car specially designed for the purpose, and this car will be provided with power for handling the weights rapidly by means of a specially designed crane.

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* Communicated by the Bureau.

CONFERENCE ON WEIGHTS AND MEASURES.

The Eighth Annual Conference on Weights and Measures was held May 14–17, 1913, at the National Bureau of Standards in Washington. Representatives of the various States and cities having weights and measures officials were present. This Conference is the coöperative effort on the part of those interested in weights and measures to place the inspection service upon a thorough scientific and practical basis. A notable feature of the reports was with respect to the large number of States which had adopted, in whole or in part, the model weights and measures law recommended by the Conference.

The Secretary of Commerce, Hon. William C. Redfield, delivered the address of welcome. Dr. S. W. Stratton, the Director of the Bureau, presided at the Conference. The principal technical papers related to the testing of gas meters (M. H. Stillman, Bureau of Standards), testing of water meters (W. F. Stutz, Bureau of Standards), design of capacity measures (R. Y. Ferner, Bureau of Standards). Chief Engineer A. Bousfield, of the Fairbanks Company, gave a talk on the "Design of Scales." A report on legislation for the past year was made by F. S. Holbrook, inspector of weights and measures for the Bureau of Standards. Mr. L. A. Fisher, secretary of the Conference, read the report of the work of the organization since its last meeting. Mr. R. W. Smith, of Minnesota, discussed uniformity in State laws on weights per bushel of commodities. Col. W. C. Haskell, of Washington, D. C., reported upon the difference in the amount of a bushel of a commodity when sold by weight and when sold by measure. Mr. C. A.

Briggs, of the Bureau of Standards, described some experiments on scales and weighing and certain technical features of scale action and construction. The functions of a State sealer were described by Commissioner H. H. Henry, of Vermont. Commissioner C. C. Neale, of Minnesota, discussed " Seals and the Methods of Sealing."

Probably the most important single question taken up by the Conference related to the establishment of " Tolerances and Specifications " for weights and measures. The report on this subject, presented by John C. Connors, was adopted by the Conference. A basis is thus established for the unification of the allowed tolerances on weights and measures used in daily trade.

In conclusion amendments and additions to the model law were proposed by Mr. Holbrook, of the Bureau of Standards.

In connection with the Conference an exhibition of weighing and measuring appliances was made by the manufacturers. Altogether the Eighth National Conference was the most successful which has yet been held. The proceedings will be published for general distribution by the Bureau of Standards. Appended are synopses of two of the papers. Abstracts of other papers will be published in the next number of this journal.

SCALES.

EXPERIMENTS ON SCALES AND WEIGHING—TECHNICAL FEATURES OF SCALE ACTION AND CONSTRUCTION.

By C. A. Briggs.

THIS paper dealt with technical questions of scales and weighing. The subject matter was divided into two parts.

In the first the results of tests and experiments bearing upon the subject were presented. Results of weighing under special conditions were given and devices for the experimental determination of deflections in beams and structural parts were described.

In track scales the bridge is generally constructed upon the continuous girder principle, and the distribution of a load among the supports is somewhat uncertain. An experimental method for determining this distribution was proposed.

In the second part of the paper theoretical subjects bearing upon the mechanical action of scales and their construction were given and questions relating to the development of the subject from a technical viewpoint were outlined.

It was pointed out that generally recognized engineering principles have been applied to scales only in the last few years, and that consequently considerable remained to be done in establishing satisfactory working principles and practice.

TESTING OF DRY GAS METERS.

By M. H. Stillman.

THE paper was intended to present very briefly the problems involved in testing the ordinary dry gas meter and was divided into three parts:

A. Description of the ordinary type of dry gas meter.
B. Comparison of the meter with a calibrated meter or prover.
C. Comparison of the calibrated meter or prover with the standard cubic-foot bottle.

Emphasis was laid upon the necessity of keeping the testing medium (gas or air) involved in the comparisons at very nearly constant temperature, pressure and relative humidity. Since the ordinary consumer's dry meter measures the *volume* of gas passing, the most direct and natural way to test this type of meter is to pass a *known* volume of gas through the meter and notice whether the indicated volume is correct. The present methods of accomplishing this consist generally in either:

1. Passing the testing medium (air or gas) through a standard meter and the meter under test in series.
2. Supplying the testing medium to the meter under test from a meter power.

In order to obtain correct results by the above methods, the following conditions are requisite:

1. That when using a standard test meter this meter shall correctly indicate the volume of gas passed through it.

2. That when using a prover the prover shall correctly indicate the volume of gas *delivered* by it.

3. That when using either standard meter or prover there must be very little or no change in volume of the testing medium during its passage from the standard apparatus *to* and *through* the tested apparatus.

And, in order that the above three requirements be fulfilled:

1. The meter prover or test meter must be correctly calibrated.
2. The testing medium (air or other gas) and every part of the system which might influence the temperature of the testing medium during the test must be at the same temperature and remain at very nearly constant temperature during the tests.
3. The testing medium must not during the test absorb any vapors or other gases which may change its volume appreciably.

The errors due to the use of water as a displacing and sealing liquid were briefly discussed. The paper was illustrated with lantern slides and apparatus.

NOTE ON THE CONSTRUCTION OF THERMOPILES.

By W. W. Coblentz.

WITHIN the past few years rapid strides have been made in the development of sensitive thermopiles. In this development experiments have been greatly assisted by the theoretical principles of thermopile construction enunciated by Johansen,[1] who shows that the radii of the two wires of the element must be so chosen that the ratio between the heat conductivity and the electrical resistance is the same in both. Johansen's practice, however, is poor in that he used iron wire which rusts rapidly and in that the "cold," unexposed junctions were joined directly to the metal posts in the frame supporting the junctions. This prevents the unexposed junctions from quickly attaining the same temperature as the "hot" junctions, and hence tends to cause a "drift," as was found by Moll,[2] and more recently by the writer. The "cold" junctions should be covered with receivers having the same size and emissivity as the "hot" junctions, and they should be free in the air so that there will be no drift with the variation in temperature which is caused by the incident radiation. In the Hilger thermopile, which embodies the Johansen principles, the "cold" junctions appear to be joined to the metal posts in the ivory frame, hence are liable to cause a "drift" of the galvanometer needle, as was found by Moll and others.

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[1] Johansen, *Ann. der. Phys.* (4), 33, p. 517, 1910.

[2] Moll, Dissertation, Utrecht, 1907.

It is, of course, easier to construct such a thermopile, but it is not considerate of the needs of the one who must use such devices. With this thought in mind, the writer constructs his thermopiles of bismuth and silver[3] with the "cold" junctions exposed freely in the air, and having vanes symmetrical with the "hot" junctions, which is an important, if not the most important, desideratum in thermopile construction.

The additional labor involved in constructing such a thermopile is compensated for by a greater ease of operation with a highly sensitive galvanometer, such as is required in energy measurements in the extreme ends of the spectrum.

Production and Consumption of Coal and Lignite. (*Board of Trade Journal,* Jan. 30, 1913.)—*Production.*—The production of coal in the five principal coal-producing countries of the world in 1909, 1910, and 1911 was as follows, in tons of 2240 pounds:

Countries	1909 Tons.	1910 Tons.	1911 Tons.
United Kingdom	263,774,000	264,433,000	271,899,000
Germany	146,397,000	150,372,000	*158,164,000
France	36,519,000	37,030,000	38,023,000
Belgium	23,140,000	23,532,000	*22,683,000
United States	411,432,000	447,854,000	†443,025,000

* Provisional figures.
† Including lignite.

In the United Kingdom, Germany, and France the production in 1911 exceeded that of any previous year, while in Belgium it fell below that of any of the five previous years. The average annual output in the above-mentioned countries was 870,000,000 tons in the five years 1906–1910, an increase of over 170,000,000 tons on the average of the previous quinquennium. Of the other countries, Russia alone has a production exceeding 20,000,000 tons yearly. The total known production of the world (exclusive of brown coal or lignite) was about 1,050,000,000 tons in 1911.

Consumption.—In 1911 the consumption of coal was as follows: United States (including lignite), 425,422,000 tons; United Kingdom, 184,859,000 tons; Germany, 133,437,000 tons; France, 57,133,000 tons; Russia, 28,298,000 tons; Belgium, 24,126,000 tons.

Lignite.—The statistics of lignite production show that the chief producing countries are Germany, Austria, and Hungary, which in 1910 produced 68,430,000 tons, 24,729,000 tons, and 7,610,000 tons respectively; in 1911 the output in Austria was 24,859,000 tons, with 72,575,000 tons in Germany. The lignite produced in the United States is included in the figures for coal.

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[3] Coblentz, *Bull. Bur. Standards,* 9, p. 7, 1912.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, May 21, 1913.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 21, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 46.

The following proposed amendment to the By-Laws was presented for first reading:

Article IV, Section I, of the By-Laws to be amended by striking out everything after "January," in the third line, and substituting the following words: "March in each year shall pay, in advance, for the current year, one-half of the annual dues," so that the section as amended will read:

> "The annual payment of fees for membership shall be due and payable on the first of October in each year, in advance; but all members elected after the 31st of March in each year shall pay, in advance, for the current year, one-half of the annual dues."

The Chairman announced that the object of the meeting was to present the Elliott Cresson Medal to the distinguished scientists who had been recommended for this award by the Committee on Science and the Arts, and called upon Dr. Harry F. Keller to introduce them.

Dr. Keller then introduced Mr. Emile Berliner, of Washington, D. C., Dr. Isham Randolph, of Chicago, Ill., and Dr. Charles Proteus Steinmetz, of Schenectady, N. Y.

The Chairman presented the medal and certificate to each of these gentlemen.

Dr. Keller read letters of acknowledgment from Lord Rayleigh and Sir William Ramsay, of London, and Dr. Emil Fischer, of Berlin, Germany, to whom the award had been forwarded through the United States Government.

Addresses were then made by the recipients of the medals, as follows:

"Development of the Talking Machine," by Mr. Emile Berliner.

"The Imaginative Faculty in Engineering," by Dr. Isham Randolph.

"Some Electrical Problems Awaiting Solution," by Dr. Charles P. Steinmetz.

After a vote of thanks to the speakers the meeting adjourned.

R. B. OWENS,
Secretary.

[A full account of the meeting will appear in the July number.]

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 7, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 7, 1913.

MR. J. A. P. CRISFIELD *in the Chair.*

The following report was presented for final action:

No. 2526.—C. Francis Jenkins's Motion-Picture Apparatus. Referred back.

The following new subjects were accepted for examination:

No. 2534.—Reno's Escalator.
No. 2535.—Tirrell Voltage Regulator.
No. 2536.—Coolidge's Malleable Tungsten.
No. 2537.—Cooper-Hewitt Mercury Rectifier.
No. 2538.—Pohle Air-Lift.
No. 2539.—Duplex Copper-Steel Wire.
No. 2540.—Upton & Lewis's Fatigue Testing Machine.
No. 2541.—Guillaume's Alloy "Invar."

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, April 24th, at 8 o'clock.

The meeting was called to order by the president of the section, Mr. George R. Henderson, who introduced Mr. J. M. Rusby, M.E., Engineer of Tests, United Gas Improvement Company, and member of the Institute.

Mr. Rusby presented a communication on "Industrial Combustible Gases," in which he dealt with the qualities and origin or methods of production of the important gases used in the arts.

After describing the physical properties of the various gases, the speaker reviewed their origin and, in the case of the artificial gases, described methods of their manufacture.

He then considered in detail the advantages of coal, oil, and carburetted water gas for domestic purposes.

His remarks were interesting and were well illustrated by numerous lantern slides.

A brief discussion followed Mr. Rusby's paper, and, after a vote of thanks to the speaker, the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the section was held on Thursday evening, May 1st, at 8 o'clock, in the Hall of the Institute.

The meeting was called to order by the president of the Institute, who introduced Dr. Ralph Modjeski, Consulting Engineer, Chicago, Ill.

Dr. Modjeski presented a communication on "The Design of Large Bridges, with Special Reference to the New Quebec Bridge."

As an introductory, the speaker dealt with the properties of materials used in modern bridge construction. He then considered salient features of the design of several completed structures and also of some in course of construction.

His remarks on the Quebec Bridge referred to the original design and to the causes of failure of the first bridge. He concluded with a description of the new bridge.

Dr. Modjeski illustrated his paper with lantern slides and diagrams of full-size chord sections. Through these media his remarks were especially interesting and instructive.

Adjourned.

William E. Bullock,
Acting Secretary.

ON THE TRAIL OF THE SPANISH PIONEERS.

Mr. Frederick Monsen, F.R.G.S., artist and explorer, again delivered a lecture in the Hall of the Institute on the evening of Friday. April 25, 1913, on this occasion describing the country traversed by the Spanish pioneers, early in the sixteenth century, under the leadership of Hernando Cortes. Incidentally the speaker discussed the present conditions in Mexico and the southwestern portions of the United States.

The natural wonders of these countries were shown and described by means of beautifully-colored lantern slides made from photographs taken by Mr. Monsen, interspersed by many interesting tales of travel and exploration.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting of the Board of Managers, May* 14, 1913.)

RESIDENT.

Mr. Leo D. Firman, 1730 Girard Avenue, Philadelphia, Pa.
Mr. Nathan Hayward, 1230 Arch Street, Philadelphia, Pa.
Mr. W. H. Heulings, Jr., The J. G. Brill Company, Philadelphia, Pa.
Mr. Joseph D. Israel, The Philadelphia Electric Company, Tenth and Chestnut Streets, Philadelphia, Pa.
Mr. Charles H. Lawall, 39 South Tenth Street, Philadelphia, Pa.

Mr. William Maul Measey, 1328 Chestnut Street, Philadelphia, Pa.

Mr. David R. Richie, S. L. Allen & Co., Fifth and Glenwood Avenue, Philadelphia, Pa.

Mr. Robert W. Withington, American Insulating Machinery Company, Philadelphia, Pa.

Mr. E. A. Wolfe, Westinghouse Electric and Manufacturing Company, North American Building, Philadelphia, Pa.

NON-RESIDENT.

Mr. Willard S. Atkinson, Ashland, N. J.

Prof. Ernest J. Berg, Department of Electrical Engineering, University of Illinois, Urbana, Ill.

Mr. A. W. Berresford, The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.

Mr. John W. Brassington, The Pusey & Jones Company, Wilmington, Del.

Mr. H. W. Buck, 49 Wall Street, New York, N. Y.

Dr. M. E. Cooley, Dean, Department of Engineering, University of Michigan, Ann Arbor, Mich.

Mr. G. L. Coppage, The Pusey & Jones Company, Wilmington, Del.

Mr. Ernest H. Davis, The Edison Electric Illuminating Company, Williamsport, Pa.

Mr. Alex. Dow, 18 Washington Avenue, Detroit, Mich.

Mr. Thomas Duncan, Duncan Electric Manufacturing Company, LaFayette, Ind.

Mr. Charles L. Edgar, Edison Electric Illuminating Company, 70 State Street, Boston, Mass.

Mr. Carleton Ellis, 92 Greenwood Avenue, Montclair, N. J.

Mr. Frank R. Ford, 115 Broadway, New York, N. Y.

Mr. Albert H. Gfrorer, Box 145, West New Brighton, N. Y.

Mr. B. Gherardi, American Telephone and Telegraph Company, 15 Dey Street, New York, N. Y.

Mr. P. G. Gossler, A. B. Leach & Co., 149 Broadway, New York, N. Y.

Mr. Edwin W. Hammer, 55 John Street, New York, N. Y.

Mr. J. W. Howell, General Electric Company, Harrison, N. J.

Mr. Thaddeus Merriman, 165 Broadway, New York, N. Y.

Mr. Charles H. Merz, 32 Victoria Street, Westminster, London, Eng.

Dr. Ralph Modjeski, 220 South Michigan Avenue, Chicago. Ill.

Mr. William S. Murray, The N. Y., N. H. & Hartford Railroad Company, New Haven, Conn.

Mr. H. S. Noble, Renovo, Pa.

Mr. A. P. Prendergast, Superintendent of Motive Power, The B. & O. Railroad Company, Baltimore, Md.

Lieut.-Col. Samuel Reber, Army Building, 39 Whitehall Street, New York, N. Y.

Mr. E. W. Rice, Jr., General Electric Company, Schenectady, N. Y.

Mr. Robert Ridgway, 154 Nassau Street, New York, N. Y.

Mr. Russell Robb, Stone & Webster, 147 Milk Street, Boston, Mass.

Mr. Dwight P. Robinson, Stone & Webster Engineering Corporation, 147 Milk Street, Boston, Mass.
Mr. F. A. Seiberling, The Goodyear Tire and Rubber Company, Akron, O.
Mr. S. D. Sprong, Edison Electric Illuminating Company, 360 Pearl Street, Brooklyn, N. Y.
Mr. W. C. Spruance, Jr., E. I. du Pont de Nemours Powder Company, Wilmington, Del.
Mr. Charles A. Stone, Stone & Webster, 147 Milk Street, Boston, Mass.
Mr. Charles W. Stone, General Electric Company, Schenectady, N. Y.
Mr. F. M. Tait, The Dayton Power and Light Company, Home Telephone Building, Dayton, Ohio.
Mr. F. L. O. Wadsworth, 1347 Oliver Building, Pittsburgh, Pa.
Mr. W. F. Wells, 360 Pearl Street, Brooklyn, N. Y.

Changes of Address.

Dr. Louis Duncan, 50 Church Street, New York City.
Mr. J. McGowan, Jr., Box 287, Camden, N. J.
Mr. Horace C. Knorr, Primos, Pa.
Mr. John C. Nowell, 210 Post Street, San Francisco, Cal.
Mr. Lucien E. Picolet, P. O. Box 4, Bala, Pa.

NECROLOGY.

Mr. J. W. Ridpath, Jenkintown, Pa.

LIBRARY NOTES.

Purchases.

Adler, A. A.—The Theory of Engineering Drawing. 1912.
American Electrochemical Society.—Transactions, vol. 22. 1912.
Barclay, W. R., and C. H. Hainsworth.—Electroplating. 1912.
Bradley, F. A.—Pumping and Water Power. 1912.
Barthel, C.—Die Methoden zur Untersuchung von Milch und Molkereiprodukten. 1911.
Blondel, A. E.—Synchronous Motors and Converters. 1913.
Darling, C. R.—Pyrometry. 1911.
Engineering Index Annual. 1912.
French, A. W., and H. C. Ives.—Stereotomy. 1911.
French, T. E.—A Manual of Engineering Drawing. 1911.
Frye, A. I.—Civil Engineers' Pocket-book. 1913.
Hatschek, E.—An Introduction to the Physics and Chemistry of Colloids. 1913.

HEARSON, H. R.—The Manufacture of Iron and Steel. 1912.
HIRSCHFELD, C. F., and T. C. ULBRICHT.—Gas Power. 1813.
HOOKER, A. H.—Chloride of Lime in Sanitation. 1913.
JANSKY, C. M.—Electrical Meters. 1913.
MCLOUGHLIN, T. S.—Questions and Answers on the National Electrical Code. 1912.
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BOOK NOTICES.

A Text-Book of Physics, by H. E. Hurst and R. T. Lattey. 3 volumes, illustrations, 12mo. New York, D. Van Nostrand Company, 1912. Price, in cloth, $4.

This text-book is published in three volumes. Vol. I contains Dynamics and Heat; Vol. II, Magnetism, Statical Electricity, and Current Electricity; Vol. III, Sound and Light. "The scope of the book was primarily the Preliminary Examination in Physics in the Oxford Natural Science School, but a certain amount of additional matter has been introduced to render the treatment more complete and more generally useful." The subject-matter has been well selected and the treatment is clear and concise. At the end of each chapter there are a number of excellent examples. The fundamental principles and laws are well illustrated with experiments which are so carefully described that the book can be used as a laboratory manual. On this account it has a decided advantage over many of the present texts on this subject. It is the reviewer's opinion that a brief outline of the electron theory of electricity, of the properties of the X-rays and the radiations from the radioactive substances, and also a description of some of the more sensitive optical instruments, such as the Lummer-Brodhun photometer, the Michelson interferometer, and the diffraction grating, together with a few of their applications to measurements of precision, would greatly increase the usefulness of the book. The volumes deserve serious consideration by all who are interested in teaching the elements of physics.

JAMES BARNES.

PUBLICATIONS RECEIVED.

The Motor and the Dynamo, by James Loring Arnold, Ph.D., Professor of Electrical Engineering, New York University. 178 pages, illustrations, 8vo. Easton, Chemical Publishing Company, 1913. Price, in cloth, $1.50.

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Konstant auftretende secundäre Maxima und Minima in dem jährlichen Verlauf der meteorologischen Erscheinungen von Dr. Van Rijckevorsel. Achte Abteilung. 22 pages, illustrations, tables. Rotterdam, W. J. Van Hengel, 1913.

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CURRENT TOPICS

The Heat Treatment of Gun-metal. Anon. (*Brass World,* ix, 4, 139.)—A paper by H. S. and J. S. G. Primrose, read before the British Institute of Metals. The gun-metal used consisted of a mixture like Government bronze, containing copper, 88 per cent., tin 10 per cent., and zinc 2 per cent. The physical tests are. tensile strength 31,360 pounds (14 tons) per square inch, and elongation 7.5 per cent. It is very difficult to obtain sound castings from this mixture which will stand a high water pressure. Although the castings may be free from blowholes, still they are not completely satisfactory when submitted to physical and hydraulic pressure. The results obtained were: (1) Tests show that no improvement may be expected from quenching, which lowers the strength of the material. (2) Simple annealing of the metal for 30 minutes very considerably increases its strength and elongation; the best results are obtained after annealing at 700° C. (3) The homogeneity and other physical properties of the metal are correspondingly improved, but particularly the capability of the castings to withstand hydraulic pressure. (4) These results are considered to be due to the removal of the eutectic from the microstructure, which after annealing shows only the crystals of a solid solution. (5) It is anticipated that this heat treatment will minimize corrosion difficulties.

Absorption of Gases by Charcoal. Anon. (*Eng.,* xciv, No. 2451, 846.)—The recent researches of Professor Dewar have drawn attention to the extraordinary absorptive power of charcoal, especially cocoanut charcoal, for gases, and now very extended use is made of this charcoal in gas and vacuum bulb researches. According to Prof. W. Hempel and Dr. G. Vater, the charcoal obtained by carbonizing blood is superior even to nut charcoal, and much depends on the temperature at which carbonization is effected. They investigated a great many other porous agents besides charcoal, such as Kieselguhr, pumice-stone, bog ore, spongy platinum, bone ash, and a great many elementary gases, as well as $CO_1CO_2CH_4$, C_2H_6, etc., at the temperatures 20° C., —78° C., and —185° C., and found that charcoal was superior to all others, and that a particular kind of blood charcoal, prepared by stirring commercial animal charcoal with blood and water to a rather stiff paste, was superior even to the nut charcoal. The best temperature for carbonizing both kinds of materials appears to be 600° C. Even with this particular blood carbon, the investigators failed to effect a complete separation of diatomic gases, though the adsorptive powers varied considerably for different gases.

Units of Quantity of Radium Emanation. J. and G. DAUNE. (*Archives d'El Médicale,* xx, p. 521.)—The International Congress at Brussels in 1910 decided on a unit for RaEm, this unit being the amount of emanation in equilibrium with 1 gramme Ra and defined as a "curie." More convenient practical units for some purposes are the milli-curie and the microcurie, equal to 10^{-3} and 10^{-6} curie respectively. In terms of the older units, 1 curie $= 4.80 \times 10^{-5}$ gramme seconds, or 2.5×10^{9} maché units. [The gramme second is the amount of emanation produced by 1 gramme Ra per second. The Maché unit is the quantity of RaEm without disintegration products which produces a saturation current of 10^{-3} electrostatic units in a chamber of large dimensions.] Such units as a volt-hour, etc., which have often been used, have no meaning apart from the capacity of the particular instrument employed.

Magnetic Properties of Nickel and Manganese Steels. E. COLVER-GLAUERT and S. HILPERT. (*Faraday Soc. Trans.,* viii, 134.)—A series of nickel and manganese steels was investigated as to the influence of thermal treatment on their magnetic and metallographic properties, and the following are the conclusions arrived at. There is a distinct connection between thermal treatment and magnetic properties, but no definite connection between metallographic structure and the magnetic properties. Any modification which is produced by quenching these alloys from 1200° C. is in all cases strongly magnetic at room temperature; in the case of the 25 per cent. nickel steel, two superimposed temperature-hysteresis loops exist. Further, it is possible to define various constituents by their magnetic properties, and the metallographic structure of artificial nickel-iron alloys closely approximates that of meteoric iron. The allotropic theory of the magnetic properties of iron alloys is not supported by the facts.

Improving Noisy Gearing. ANON. (*Eng.,* xciv, No. 2448, 761.)—*Machinery* states that a simple method of lessening the noise of gearing has been found successful on a large scale in some St. Petersburg shops. For gears less than 18 inches in diameter two sheets of tin are fitted, one on each side of the wheel, so as to box in the space between the rim and the boss, the sheets being screwed to the rim. The space between the sheets is filled with sawdust and No. 4 shot, to eliminate vibration. When the diameter of the gears is greater than 18 inches, wooden rings are used instead of tin, attached in the same manner. A felt packing is used to prevent the sawdust leaking out. This arrangement not only reduces the amount of noise produced by the gearing, but it also has the advantage of closing the spaces between the spokes of the wheel, and so making it impossible for a workman to get his arms or tools caught in the wheel.

Photographic Recording of Ballistic and other Rapid Phenomena with the Aid of the Quenched Spark. C. Cranz and B. Glatzel. (*Deutsch. Phys. Gesell.*, xiv, 10, 525.)—After a brief review of the methods used earlier for recording photographically rapidly-occurring processes, such as ballistic phenomena, the authors describe their method, which enables a regular succession of pictures to be taken of a single bullet fired from a pistol, on a falling photographic plate. A direct current quenched gap (of the Scheller type using alcohol) is used, connected to 700-volt mains. The capacity in the gap circuit is made up of mica condensers variable from 25,000 to 600,000 centimetres; the inductance is kept very low. This inductance and that of the secondary (equal to 1800 centimetres) are in the form of flat spirals so as to secure very close coupling. In the secondary is a small spark-gap (used to illuminate the object to be photographed) shunted by a condenser. The exposures are made on a film which runs over two drums of 89 centimetres circumference, capable of making 9000 revolutions per second. It is found that the number of sparks passing can be adjusted accurately to any number between 200 and 100,000 per second by (1) altering the capacity in the primary circuit; (2) regulating the intensity of the current in the primary. Reproduced photographs show the method's capabilities. With 6400 sparks per second, the firing of a shot at a piece of wood is seen in all its phases. With 10,000 sparks per second, the movements of the cartridge in the operation of an automatic pistol can be followed. Other records show the bullet issuing from the muzzle, and the accompanying phenomena, taken with spark frequencies of 56,200, 72,000, and 92,200 per second. The possible application of this method to investigate electric double refraction is also mentioned.

Influence of Oxygen on the Properties of Metals and Alloys. E. F. Law. (*Inst. of Metals Journ.*, viii, p. 222.)—Attention is drawn to the great influence exerted by oxygen when present in metals and alloys. Although recognized by practical men, the scientific side of the question has been neglected. It is pointed out that a chemical analysis of copper which failed to report 0.1 per cent. of lead would be considered unsatisfactory, yet it frequently happens that ten times as much of cuprous oxide is not reported. The omission is more serious than it appears at first sight, because the oxides, having lower specific gravities than the metals, occupy a larger volume, and the influence exerted by an impurity depends upon its volume and not on its weight. From cases examined, it appears that metallic oxides are insoluble, or practically insoluble, in metals and alloys, and occur as particles varying in size and distribution, entangled and embedded in the metal. Photomicrographs are given illustrating the pressure of oxides in bearing bronze, arsenical copper from a locomotive fire box, and also a series to show the effect of increasing additions of arsenic to oxidized copper. As regards the effect of the presence of oxides on mechanical tests, the minimum effect is produced when the oxide occurs in the massive form, and the maximum effect when the oxide occurs as a network between the crystals. Abnormal corrosion of metals, also pitting and local deterioration, etc., are, in most cases, due to the presence of non-metallic impurities, and in all investigations of corrosion the presence of oxides must be taken into account.

New Prussian Regulations for Inks. F. W. HINRICHSEN. (*Chem. Zeit.*, xxxvii, 265.)—According to the new Prussian regulations for 1912 inks are classified into (1) "documentary" and (2) "writing inks," the latter being subdivided in (*A*) iron-gall inks, and (*B*) logwood and dyestuff inks. (1) A "documentary" ink is defined as an iron-gall ink which gives dark writing after 8 days' exposure to light and air. It must contain at least 27 grammes of anhydrous gallotannic and gallic acids and 4 grammes of iron (calculated on the metal) per litre. On the other hand, the amount of iron must not exceed 6 grammes, so that the ratio of gallotannic and gallic acids to iron must lie within the limits 4.5 : 1 and 6.75 : 1. The ink must not alter for at least 14 days in the inkpot, and must flow readily from the pen. The writing done with it must not be sticky immediately after drying, and after 8 days it must remain deep black when washed with water and with alcohol of 85 and 50 per cent. (2) Iron-gall "writing inks" (*A*) must contain at least 18 grammes of gallotannic and gallic acids, and at least 2.6 and not more than 4 grammes of iron (ratio 4.5 : 1 and 6.75 : 1). In other respects they must comply with the requirements of "documentary" inks. Inks of group *B* are not officially tested. Then follow the methods prescribed for the analysis of the inks.

Iron and Nitrogen. J. H. ANDREW, M.Sc. (*Eng.*, xciv., No. 2451, 860.)—This most interesting paper is supplied with diagrams and photomicrographs, showing the effect of the nitrogen absorbed by iron. The conclusions arrived at are: Iron and iron-carbon alloys absorb small amounts of nitrogen when melted under a high pressure of the gas. The absorption of 0.3 per cent. of nitrogen entirely suppresses the critical changes occurring in pure iron, and prolonged heating *in vacuo* is required to denitrogenize the metal. The absorption of 0.25 per cent. of nitrogen by a 0.6 per cent. carbon steel lowers the Ar 1 point to a marked degree. Such a nitrogenized steel can only be restored to the normal state of a pure steel by several weeks' heating *in vacuo*. It is considered that the critical changes occurring in iron and steel are due to the coalescence of like molecules, and that this coalescence is due to the contraction of the metal during cooling, bringing the molecules sufficiently near together for the force of the molecular attraction of like molecules to exert itself and overcome the influence of the intervening molecules. The absorption of nitrogen, followed by the formation of iron nitride, prevents the iron molecules and the iron carbide molecules from coalescing with molecules of their own kind by keeping them farther apart. This will necessitate greater contraction of the metal, and therefore a lower temperature, before the like molecules are brought sufficiently near together for the force due to molecular attraction to effect a change. The effect of nitrogen upon the mechanical properties is made evident by considerations of its influence upon the critical change. Hydrogen has no influence upon the critical changes when introduced into the liquid metal under pressure. The influence of nitrogen upon the mechanical properties is the increase in tenacity and hardness and the decrease in elongation; this is readily understood when it is shown that nitrogen tends to retain the iron in the gamma state and the carbide in solution. The small specimens dealt with were intensely hard and brittle, the samples with a higher carbon content being more so than those containing only a small percentage of carbon. A most remarkable feature is the exceedingly small amount of nitrogen necessary to cause a great effect, and the difficulty in extracting the last traces of the gas from the metal. Iron nitride is not, therefore, the unstable compound that it is generally supposed to be. It appears necessary to remelt the nitrogenized iron in order to extract the gas.

The Yellow Discoloration of Paper. VIKTOR SCHORLLER. (*Wochbl. Papierfabr.,* xliii, 3222.)—Papers containing mechanical wood pulp discolor very readily with age, and papers containing straw and esparto pulp are subject to discoloration. Chemical wood pulp turns yellow to a less degree, while paper made entirely from rags suffers slight discoloration. The coloring may be due to: (1) destruction of the ultramarine or other blue color used in the manufacture; (2) actual yellowing of some component of the paper. The color of ultramarine may be destroyed by atmospheric oxidation or by acid residues in the paper, causing the sheet to return to its natural yellow color. There may also be discoloration from external causes, such as exposure to coal-gas, etc. The liability of a paper to discolor may be determined by: (1) allowing to lie in the dark for at least one year; (2) exposing to action of air and light for about one week; (3) heating under uniform moisture conditions at 95° C. for 3, 15, and 30 hours. The intensity of color developed by warming indicates the discoloration to be expected when the paper has aged. Unsized, unbleached cotton or linen half-stuff shows no tendency to discolor. Moderately-bleached stock, washed immediately after bleaching, does not discolor, but overbleached stock, or one that has been allowed to rest in the drainer for even one day before washing, will turn yellow with age. This is due to the oxidation of the cellulose fibres. The most important cause of the discoloration of paper is the rosin size. All rosin-sized papers turn yellow. This may be due to: (1) the reagent used to precipitate the size; (2) formation of rosin-iron compound; (3) oxidation of the rosin by atmospheric oxidation; (4) auto-oxidation, or polymerization of the rosin. The precipitant used has little effect on discoloration. Experiments showed that papers sized with rosin precipitated by commercial aluminum sulphate, acetic acid, magnesium sulphate and acetic acid, carbonic acid, alum, hydrochloric acid, and from alcoholic solution by water, turned yellow on heating to the same extent. Comparative tests showed that within the limits of commercial practice the presence of iron or of iron resinate has little effect on the coloration of paper. Nevertheless, care must be taken to use an alum low in iron. Discoloration due to the action of atmospheric oxidation on rosin is very slight in all cases, but rosin develops a darker color on standing, due to polymerization or auto-oxidation, and it is to this fact that the discoloration of rosin-sized papers is chiefly due. By previous treatment of the rosin with bleaching-powder this polymerization may be effected, and size made from rosin so treated has no effect on the discoloration of paper.

Reactions Accompanying the Osmosis of Hydrogen through Iron. G. CHARPY and S. BONNEROT. (*Comptes Rendus,* clvi, 394.)—Experiments on the osmosis of hydrogen through iron show that the gas is not absorbed by the metal, for the volume of gas extracted by heating *in vacuo,* even after prolonged passage of hydrogen, is found to be generally less than that obtained before osmosis, and hence it is concluded that iron and steel which have been manipulated without special precautions, in contact with air, are as a rule saturated with hydrogen. This is explained on the supposition that the nascent hydrogen, continuously produced on the surface of the metal each time it is heated, from the reaction with atmospheric moisture, immediately penetrates the metal. As might be expected, therefore, the properties of iron are not sensibly affected by the osmosis of hydrogen unless after a very prolonged passage of the gas, when the metal gradually softens. This is due to the reducing action of the hydrogen, which removes such impurities as phosphorus and sulphur as hydrides; desulphurization is especially marked. Carbon monoxide is generally present in the gas after osmosis, due to the action of water vapor (formed by the reduction of oxidized substances present in the metal) on the carbon or iron carbide also present, and hydrocarbons are formed by the direct action of hydrogen on iron carbide. The reducing action of hydrogen is quite distinct at 700° C. and increases rapidly with the rise of temperature, so that osmosis may be used as a means for getting rid of the last traces of certain impurities from iron; and it is pointed out also that modification by hydrogen must go on in any ferrous metal which is submitted to successive heating and cooling. It is considered that hydrogen probably plays an important part in connection with many changes which may be effected in the solid metal and which must often be accompanied by the absorption or elimination of hydrogen.

Petroleum Production in the United States. ANON. (*Board of Trade J.*, Feb. 27, 1913.)—The preliminary estimates place the production of petroleum in the United States in 1912 at 220,200,000 barrels (each of 42 United States gallons), valued at $150,000,000, or 68 cents per barrel, as compared with 220,449,301 barrels, valued at $134,044,752, or 61 cents per barrel, in 1911. The year 1912 is the first year since 1859 in which the quantity produced has not shown an increase. The California output of low-grade oil reached 87,000,000 barrels, an increase of about 6,000,000 barrels over last year's figures. This increase was counterbalanced by the decreased production in the high-grade fields, with the exception of West Virginia, where the production increased by about 2,000,000 barrels. Oklahoma and Illinois still maintain their position in the high-grade field, as they are jointly responsible for about two-thirds of the total output. Last year, however, showed a decline in Oklahoma, as the average for the year was only 50 barrels per well, compared with 73.4 barrels in 1911. No new States were added to the list of producers in 1912, but Wyoming and Michigan, hitherto only small producers, gave promise of becoming of greater importance. With the exception of California, where overproduction and other causes made prices very low, the price of crude oil steadily advanced throughout 1912. This rise was due to fundamental conditions and not to manipulation. Last year production remained steady, while consumption increased so as to result in a shortage, and prices would have gone even higher but for the surplus for previous years in store. The price of very high grade Pennsylvania oil rose from $1.35 to $2.00 per barrel at the well. In the year 1912 there was a marked increase in the number of independent oil refineries, especially in Illinois and Oklahoma.

Machine Mining of Coal. ANON. (*Amer. Mach.*, xxxviii, 9, 340.)—The coal report for 1911, recently issued by the United States Geological Survey, throws an interesting light on the improved methods of coal mining. In 1911, 13,819 machines were used in mining coal, 565 more than in 1910. The leading coal-producing State is Pennsylvania, and it also leads in the total tonnage mined by the use of machines, and in the number of machines used; but Ohio outranks all other States in the proportion of machine-mined coal to the total output.

Heating Effect of Radium. E. RUTHERFORD and H. ROBINSON. (*Eng.*, xciv, No. 2442, 549.)—Professor Rutherford states that a large amount of work has been done on this problem since Curie's time, but they were still uncertain as to two fundamental questions: Was the energy of the radiations a measure of the heating effect, and was the heating due to the α particles, the chief product, or also to other products? Radium and RaA gave α particles, RaB gave β and γ particles, and RaC gave α, β, and γ particles. There might be disintegration before the ejection of the α particle, and also rearrangement of the residual atom after the ejection. Geiger had shown that there was a relation between the rate of decay and the velocity of expulsion. In his new measurements he had applied his own and Barnes's method, using a differential water calorimeter. The tube containing the emanation was placed within a platinum coil and the galvanometer current was balanced. When the calculations were first made on the assumption that the heating was all due to α particles, it was found that the α particles alone could not account for the full heat effect. Experiments were then made to separate the effect of the β and γ particles from the α particles by the aid of very fine glass tubes placed in mercury within the calorimeter. There was uncertainty both as to the measurements and the standards, and they did not exactly know what they measured; but the results agreed with those of Meyer and Hess, and they indicated that the heating effect of radium agreed with the energy of the radiation, except that there was a slight deficiency as to RaC, which was known to emit γ rays of great velocity.

Relations between the Macrostructure and Crystallization of Steel. N. T. BELAIEW. (*Rev. de Métallurgie*, ix, 647.)—From a long series of observations of the macrostructure of ordinary and alloy steels, and an examination of the developed crystals often found in the pipes and cavities in ingots, it is concluded that cast steel is composed, both externally and internally, of crystals similar to those developed in the pipes and cavities. The size, shape, and distribution of the crystals depend upon the mass, section, and composition of the ingot and also upon the method of cooling, etc. These crystals are produced during the period of solidification, and their formation is revealed by the macrostructure, which is a result of irregularities in composition and is typical for all classes of steel. In general, the macrostructure cannot be modified at the temperatures attained in the course of ordinary thermal or mechanical operations, so that it really represents the stable structure of the steel. Cold mechanical work only produces deformation of the crystals, while hot treatment only produces local changes in each of the particles constituting the macrostructure. Consequently the difference between the three types of steel is: (1) Cast steel is made up of crystals of various shapes and sizes, arranged haphazard; (2) mechanically-worked steel consists of the same crystals more or less displaced, according to the nature and degree of working; and (3) thermally-worked steel is always made up of the same primitive crystals, either in their natural or deformed state, but the constituent parts of the crystals have been altered as a result of equilibrium changes determined by temperature and other conditions of the thermal treatment.

The Physico-chemical View of the Staling of Bread. J. R. KATZ. (*Z. Elektrochem.*, xix, 202.)—The view is advanced that the change from fresh to stale bread is a reversible transformation, stale bread being the form stable at low temperatures, 0° to 25° C., and fresh bread stable at higher temperatures, 50° to 100° C. No exact transition point can be determined. Fresh bread can be preserved in liquid air, on account of the very low speed of transformation at low temperature. On the basis of these experiments it is suggested that bread may be kept fresh, and night work in bakeries avoided, either by storage at 60° to 100° C., or in a refrigerating chamber.

Zirconium. E. WEDEKIND. (*Annalen,* cccxcv, 149.)—The preparation of metallic zirconium by means of magnesium or by the alumino-thermic method was unsatisfactory, but good results were obtained by a method devised by the author and H. Kuzel. Pure zirconium oxide was intimately mixed with an excess of metallic calcium as finely divided as possible. The mixture was placed in an iron tube which was exhausted to about 0.5 to 0.1 mm. The bottom of the tube was heated with a blowpipe till the reduction began, after which the tube was cooled by blowing air on it and finally dipping in water. When quite cool the contents were rapidly pulverized and treated first with water which had been boiled and cooled, next with acetic acid, finally with very dilute hydrochloric acid. Air should be excluded during the whole of the treatment. The residue was finely powdered and again digested with boiled dilute hydrochoric acid. The powder was filtered off and washed with air-free water till the spectroscopic calcium reaction was no longer given. The water was removed by acetone and the powder dried in an exsiccator at ordinary temperature and then dried in a high vacuum at 250° to 300° C. The portion for analysis was further dried in a completely exhausted porcelain tube at 800° to 1000° C. This was done in a small kryptol furnace. A regulus was thus obtained which on filing and polishing gave a fine metallic surface which did not oxidize in air. The yield was about 97.5 per cent. The metal contained 97.7 per cent. of free zirconium. The specific gravity of the powder at 18 °C. was 5.98 and of the fused (sintered) metal at 17.5° C., 6.204. The metal was completely melted (not sintered) by making an arc between zirconium electrodes *in vacuo* in the Weiss-Neuman furnace. The specific gravity of the completely melted product was 6.44 at 16° C. The calcium method has been applied to other refractory metals,—*e.g.*, titanium, thorium, tantalum, etc. The melting point of this titanium was 1530° C., according to G. K. Burgess and 2350° C. according to v. Bolton. Burgess melted the metal on platinum, but his method has given good results with iron, chromium, etc., and it is probable that v. Bolton's result is too high, owing to the formation of zirconium oxide, with a melting point of about 2500° C. A sample of zirconium hydride, considered to have the formula ZrH_4, was found to contain some oxide, and the formula ZrH_2 was found for the hydride. The oxide obtained on oxidation does not appear to be ZrO_2, nor does it correspond to the suggested Zr_2O_3. A new compound, the nitride, Zr_3N_2, was obtained by heating the metal in nitrogen at 1050° C. On passing hydrogen over the nitride for 15 minutes at 1050° C., 8.7 per cent. (87 per cent.?) of the theoretical yield of ammonia was obtained. The so-called amorphous zirconium was obtained by Berzelius's method by heating potassium zirconium fluoride with potassium in an iron tube. On heating this powder it often becomes pyrophoric. It contains only about 35 per cent. of free zirconium. Its characteristic feature is its great surface; it is like a colloidal gel and retains water with great tenacity. With acids it easily passes into a hydrosol. The hydrogel precipitated from this hydrosol is very similar to the amorphous ziroconium.

Emission of Charges in Vacuo. E. HENRIOT. (*Le Radium,* ix, 224.)—Two elements, potassium and rubidium, are clearly distinguishable, by a radiation analogous to that from radioactive bodies, from ordinary substances whose activity is doubtful. Potassium emits β-rays approximately homogeneous and easily deviable, with a penetrating power about equal to that of the β-rays from uranium; this radiation is normal, atomic, and spontaneous. Rubidium emits slower β-rays, fairly homogeneous, with a penetrating power about equal to that of the β-rays from radium, with general characters like those of the rays from potassium. Potassium, rubidium, and their salts emit, spontaneously *in vacuo,* electrical charges, a great part of which, at any rate, must be attributed to ionizing β-rays.

Swedish Electric Current for Denmark. ANON. (*Eng.,* xciv, No. 2451, 862.)—Some time ago we mentioned the plan of exporting electric current from the Swedish State power station at Trollhättan to Denmark. This plan has not been abandoned, but a new scheme has been brought forward. The three falls—Skapanäsfors, Skagfors, and Atrafors, situated near each other on the river Atra—are now proposed as the source of power. They have been secured for this purpose and are calculated to yield some 17,600 horsepower locally, or 14,900 horsepower at the boundary of Copenhagen. The distance between this projected station and Copenhagen is only about half that between Trollhättan and the capital of Denmark. The entire installation, including those at Copenhagen, is estimated to cost $1,500,000.

New Method of Revealing Segregation in Steel Ingots. R. HADFIELD. (*Iron and Steel Inst. Journ.*, lxxxvi, 40.)—The method consists in pouring a little molten copper on the top of the ingot soon after pouring. If the copper is added before solidification is complete it displaces the residual molten steel, but if added after complete solidification it fills up the cavities and shows the areas of segregation. This method seems to open up a valuable source of information on the rates of cooling, segregation, and liquation, and the present results indicate that the interior of an ingot remains hot for a much longer period than was previously thought, thus providing greater opportunities for segregation.

Production of Iron and Steel in France During 1912. ANON. (*Board of Trade J.*, Feb. 20, 1913.)—According to the Bulletin of January 21, 1913, of the "Comité de Forges de France," the amount of iron and steel produced in 1911 and 1912 by the members of the association was as follows:

	Metric tons.	Metric tons.
Pig iron	4,426,469	4,826,553
Steel ingots	3,680,613	4,136,942
Steel products:		
Blooms and billets	1,744,148	2,064,072
Merchant steel	709,131	675,259
Girders and shapes	621,249	641,720
Rails	449,818	492,767
Sheets and plates	449,234	501,859
Other products	409,052	444,013

Coating Iron with Aluminum. S. UYENO, Tokio. (*Eng. Pat.* 11,836, of 1912.)—The iron article to be coated is first galvanized or tinned, and is then immersed in molten aluminum at about 700° or 800° C., and during the immersion the surface is swept by steel brushes. The tin or zinc passes into the molten aluminum, and aluminum replaces it on the iron surface. The article is treated in this manner in two or more of such baths, and the greater part of the tin or zinc is left in the first bath. It is claimed that this process causes the aluminum to adhere to the surface of the iron so well that it will not come off, nor tarnish, nor corrode under the action of air, water, or heat, and cannot be stripped off by mechanical means.

The Specific Heat of Wood. F. DUNLAP. (*U. S. Dept. of Agric.*, Bull. No. 110.)—The specific heat of a large number of samples of wood was observed by the aid of a Bunsen ice calorimeter specially adapted for the work. These samples were oven-dried at 105° C., and most of the observations were made between this temperature and 0° C. Tables are given of the detailed results; the mean specific heat of oven-dried wood is 0.327, and this is nearly constant for all kinds of wood. There is practically no variation in samples taken from different parts of the tree, and the location where the wood is grown makes no practical variation. There is a large variation in specific heat with the temperature, however, and when represented by a straight line formula the specific heat is expressed by the following equation: Specific heat $= 0.266 + 0.00116\,t$.

Sources of Supply for the Manufacture of Paper. C. BEADLE and H. P. STEVENS. (*J. Roy. Soc. Arts,* lxi, 347.)—Alluding to the supply of pulp wood, particularly in the United States, showing material signs of exhaustion, the authors then review the recent investigations of proposed new sources of supply. They consider chiefly the investigations carried out by the United States Forest Service at Wausaw on the utilization of coniferous woods of inferior quality; Raitt's investigations on bamboo; cottonseed hull fibre; bagasse, particularly the McMullen process of shredding as carried out in Cuba; Brand's investigations on American crop plants, and finally to their own experiments with *Hedychium coronarium.* The extraordinary development of this plant in Brazil is described, and also the experiments carried out with plants grown at Kew. The papers prepared from Hedychium fibre are among the strongest hitherto recorded, equal or superior to the best manila papers, and are particularly suitable for the manufacture of paper yarns for textile purposes. The following table was compiled to give a comparative survey of the possible importance of the principal new paper-making materials undergoing development:

Plant.	Acres under cultivation.	Tons per acre per annum of dry raw material.	Tons of raw fibre per annum on total area.	Percentage yield of pulp on dry raw material.	Tons of pulp per annum per acre.	Tons of pulp per annum on total area.
Cropped once a year:						
1. Corn stalks	30,000,000	1.0	30,000,000	12–18	0.12	3,600,000
2. Broom corn	178,000	3.0	450,000	32–40	1.00	150,000
3. Rice straw	720,000	2.0	1,500,000	35	0.70	500,000
4. Flax straw	2,000,000	1.0	2,000,000	30	0.30	600,000
5. Cotton hull fibres	.....	....	150,000	75	....	112,000
6. Cotton stalks	10,000,000	0.45	4,500,000	35–40	0.15	1,500,000
7. Hemp straw	....	5.0	....	20	1.00	....
8. Hedychium	....	6–10	....	60	4.00	....
Cropped every 5 years:						
9. Bamboo (Sindall)	....	15·5	....	45	1.35 to 1.57	....
10. Bamboo (Raitt)	....	8·5–18·5	....	45		....
Cropped every 40 years:						
11. Wood pulp	....	$\frac{16\text{ cds}}{40}$	....	4	0.20	....

Alloys for Casting. F. DE BUIGNÉ, Magdeburg. (*Eng. Pat.* 1346, of 1912.)—Type-metal alloys designed for casting under pressure should be capable of remaining in the molten condition for a long time without changing in composition, and should not form dirt or dross in the casting channels or moulds. Alloys composed of aluminum, copper, and tungsten, and free from zinc, fulfill these conditions. Alloys which give satisfactory results are (1) aluminum 80 to 90, copper 8 to 10, tungsten 1 to 10 parts, and (2) copper 90 to 95, aluminum 3 to 10, tungsten 0.1 to 5.0 parts. Both alloys must be free from zinc.

Production of Mirrors by Cathodic Disintegration. G. RUMELIN. (*Physik. Zeits.*, xiii, 1222.)—The plate upon which the mirror is to be produced is used as the anode and is placed on a small table in juxtaposition to a plate of the metal to be disintegrated, which serves as a cathode, all being enclosed in a glass bell resting on a ground-glass plate. The space is first exhausted, then a current of hydrogen is sent through by the help of a Gaede pump. An opaque silver mirror can be produced in 30 seconds. Mirrors of gold, silver, platinum, copper, nickel, iron, palladium, and iridium have been thus produced.

Porcelain Insulators for High-Tension Transmission Lines. J. LUSTGARTEN. (*Inst. Elect. Engin. Journ.*, xlix, 235.)—This article is a summary of past and present practice in the design, manufacture, and testing of porcelain insulators for high-tension work. The ordinary methods practised in England, Germany, and America are given, describing various types of pin insulators, and curves are shown of electric tests both in the dry and wet condition. Their protection from damage due to arcs is considered, with special reference to Nicholson's arcing rings and Hermsdorf's metal shed insulator. Where the pull is too great for the ordinary type of pin insulator, shackle insulators are used. Suspension insulators of various kinds are mentioned, including the interlink and cemented types, with drawings and photographs showing how they are liable to break down under high voltage. The electrical considerations in design, the distribution of potential gradient along the series, and means of protection against arcing effects are detailed. The methods used in various factories of setting insulators are given, including puncture tests and artificial precipitation tests. It is shown that these methods vary considerably, and a full outline of the present practice is given relating to typical methods in different countries. In conclusion, there are mathematical notes on the potential gradient and density of the electric charge on the surfaces of condensers with different kinds of dielectric. A discussion follows relating principally to matters affecting the design and testing of porcelain insulators.

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